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LAUNCH MONITOR SUBSYSTEM

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CHAPTER 1

INTRODUCTION

1.1 SYSTEM OBJECTIVES

The Launch Monitor Subsystem, as part of the Mercury tracking and ground instrumentation system, provides facilities for transmitting and processing data necessary for the ground system to perform its functions.

Data concerning a Mercury flight is collected, processed, and displayed to controlling and monitoring personnel for them to carry out their responsibilities effectively. The greater part of the data collection is not a function of the Launch Monitor Subsystem, but is accomplished by the Mercury tracking and ground instrumentation system. The implementation of the Launch Monitor Subsystem provides an added capability to collect trajectory data immediately following launch vehicle liftoff and through insertion of the capsule into orbit. From this period on, the data collection function is accomplished by the original network provided for data transmission from the remote data collection points.

Throughout the Mercury flight, data concerning the capsule is processed to derive quantities which, when displayed to controlling and monitoring personnel, enable them to evaluate the performance of the mission and exercise their command functions. The facilities concerned principally with processing input data and transmitting processed output data to the displays are capable of accommodating operations during the abort, orbit, and re-entry phases of flight, as well as during the launch phase.

The responsibility for specifying levels of accuracy, timeliness of data, and the functions of personnel in the Mercury Control Center has been retained by NASA. These factors are not considered in this document. Described in detail in this manual, however, are the specific display quantities presented to Mercury Control Center personnel.

1.2 SYSTEM FUNCTIONS

The systems and subsystems with which the Launch Monitor Subsystem operates consist principally of the overall Mercury ground system and certain subsystems of the Cape Canaveral range. The characteristics of the Launch Monitor Subsystem are influenced greatly by its interaction with these systems. The functions of these systems and the manner in which they serve as sources of data have a considerable effect upon the implementation of the Launch Monitor Subsystem.

1.2.1 Cape Canaveral Downrange Complex

The U.S. Government has the general responsibility for the launch vehicle and for placing the capsule in orbit. The Cape Canaveral downrange complex comprises the tracking and instrumentation network operated by the Cape in connection with the launching of space vehicles from there. It consists of a number of radar and telemetry receiving sites connected by data transmitting facilities to high-speed data processing equipment. In addition, necessary equipment for the ground control of vehicle guidance systems is provided.

The Cape Canaveral radars, data processing equipment, and facilities for launch vehicle guidance control are the primary segments of the Cape's range to be considered in launching the Mercury capsule into orbit.

1.2.1.1 Radar Sites

In normal Mercury launch range operations, four tracking sites are utilized. The types of radars and their locations are:

a. Azusa: Cape Canaveral

b. AN/FPS-16: Cape Canaveral

c. AN/FPS-16: Grand Bahama Island

d. AN/FPS-16: San Salvador Island

Each of these sites makes range, azimuth, and elevation measurements on a target, referenced to the site. These values are transmitted from the site to the Impact Predictor 709 building where they are utilized as inputs to the IBM 709 computer.

1.2.1.2 Impact Predictor 709

This IBM 709 computer utilizes the raw radar inputs of range, azimuth, and elevation. From these inputs it calculates the altitude of apogee and the point where the launch vehicle would impact if thrust terminated at that instant. These results are displayed to the Range Safety Officer to enable him to evaluate the safe performance of a launch operation.

1.2.1.3 Burroughs—General-Electric Guidance System Computer

This special-purpose computer is part of the guidance system of the launch vehicle. It operates in conjunction with radar and with telemetry data received from the vehicle to track the vehicle, to check its performance, and to generate the necessary commands for achieving the desired launch performance.

1.2.2 Tracking and Ground Instrumentation System

A worldwide network of radar and telemetry receiving stations gathers and processes data concerning the flight of the Mercury capsule. However, only the Cape Canaveral sites, Mercury Control Center, Goddard Computing and Communications Center, and Bermuda are utilized in connection with the Launch Monitor Subsystem.

1.2.2.1 Mercury Control Center

The Mercury Control Center and a communication system to provide for voice and telemetry transmission to and from the Mercury capsule is located at Cape Canaveral.

The Control Center houses the controlling and monitoring personnel responsible for various aspects of the Mercury flight. Data transmitted from the capsule by telemetry or data derived at the Goddard center from tracking and telemetry data is presented to control personnel here on various display devices.

1.2.2.2 Goddard Computing and Communications Center

This station is equipped with a duplexed installation of IBM 7090 computers. The computers accept input data concerning the Mercury flight and perform the computations necessary to derive pertinent orbital and trajectory parameters.

1.2.2.3 Bermuda

The Bermuda site is responsible for backing up the Mercury Control Center during the launch phase of the mission. The station monitors the launch and, in the event that the Mercury Control Center is unable to make the go-no-go decision, determines the go-no-go status of the flight. After the launch phase, Bermuda functions as a normal tracking station.

Bermuda is equipped with an IBM 7090 computer, with radar, and with voice and telemetry communications equipment. The function of the computer is to accept radar and telemetry data and compute the necessary orbital and trajectory parameters.

1.3 SYSTEM IMPLEMENTATION

The implementation of the Launch Monitor Subsystem provides the necessary facilities for collecting and transmitting data from data sources to the data processing center at Goddard, and for transmitting the processed data to the displays at the Mercury Control Center. A brief description of the implementation at various locations is given in this paragraph. A detailed description is presented later in the document.

1.3.1 Mercury Control Center

The Mercury Control Center is equipped with a number of plot boards and digital display consoles. The plot boards and digital displays, which the Launch Monitor Subsystem must accommodate, present processed data from the Goddard Computing and Communications Center and/or the Burroughs—General-Electric Guidance System Computer. Facilities are provided for transmitting this data from these other locations to the Mercury Control Center over high-speed data circuits.

Data receivers at the Control Center accept the signals from the telephone lines and convert these signals into digital information. Registers buffer and store this information prior to its being displayed. Digital-to-analog converters provide analog representations of the digital quantities for the X-Y plot boards. Switching equipment enables data from either the Goddard computer or the Burroughs—General-Electric computer to be selected for display on plot boards I, II, and III.

Buffering and transmitting equipment is provided to accept data from the capsule telemetry receiver, and command and override signals from the capsule communicator's console. The equipment transmits this data via high-speed circuits to the Burroughs—General-Electric Computer Building and to the Impact Predictor 709 Building for subsequent retransmission to the Goddard Computing and Communications Center.

1.3.2 Burroughs—General-Electric Computer Building

The equipment located at the Burroughs—General-Electric Guidance System Building consists of a unit capable of receiving and retransmitting data from the Mercury Control Center and from the Burroughs computer. Telemetry data from the Control Center, and part of the data from the Burroughs—General-Electric computer, is transmitted to the Goddard center. The remaining information from the computer is transmitted to the Control Center for display purposes.

1.3.3 Impact Predictor 709 Building

Equipment in this building accepts telemetry data from the Mercury Control Center, and either processed position and velocity data from the IP 709 computer or raw radar data from the downrange AN/FPS-16 radars. Facilities for buffering and retransmitting these inputs to the Goddard center are also provided.

1.3.4 Goddard Computing and Communications Center

The Launch Monitor Subsystem provides equipment at Goddard for transmitting and receiving data over high-speed data circuits to and from Cape Canaveral. Also provided are high-speed input and output subchannels of the computer data communications channels, plot boards for display of data, digital-to-analog converters, and a switch that selects the output of one of the computers for transmission to the Mercury Control Center.

1.3.5 Bermuda

The equipment provided at Bermuda by the Launch Monitor Subsystem consists of buffer registers and digital-to-analog converters to accept data from the computer for display on a plot board and on digital displays.

1.3.6 Data Transmission Facilities

High-speed data is transmitted over a number of high-quality telephone circuits. Output data from the Goddard center is transmitted to the Mercury Control Center over four such circuits. Each circuit carries the complete output message. A delay device is incorporated in each transmitter so that a particular bit in the message is shifted in time from its position on the other circuits.

Two circuits each from the Burroughs—General-Electric Guidance System Building and from the Impact Predictor 709 Building transmit data to Goddard. In each case, the data on one circuit is time-shifted by a delay inserted at the transmitting end.

Complementary delays are inserted in the receivers on these groups of circuits so the time relationship of bits in similar messages is in phase at the receiver output. This time shifting of data during transmission protects against transmission errors.

1.4 DATA FLOW

The system implementation described in paragraph 1.3 provides for the transmission of data from a number of sources to the Goddard Computing and Communications Center. There, the input data is processed and a large number of output data quantities are produced. This output data is then transmitted from Goddard to Cape Canaveral for display in the Mercury Control Room. The various data sources and the flow of data throughout the Launch Monitor Subsystem are briefly discussed in this paragraph.

1.4.1 Data Sources

The systems discussed in paragraph 1.2 supply considerable data on the Mercury flight. The radars and telemetry receivers provided at all Mercury tracking stations produce such data. With the exception of Bermuda and Cape Canaveral, these stations are not of concern in the Launch Monitor Subsystem.

Agreements have been made with the Cape Canaveral complex to make considerable data available from various parts of the complex. These sources together with the telemetry receiver at the Mercury Control Center, Cape Canaveral, are the data sources that must be considered as inputs to the Goddard Computers.

1.4.1.1 Impact Predictor 709

In connection with the processing of raw radar data, the IP 709 produces position and velocity vectors describing the trajectory of the vehicle concerned. Agreement has been made to transmit these values to the Launch Monitor Subsystem.

1.4.1.2 Radar

It has also been agreed that, in lieu of data from the Impact Predictor 709, range, azimuth, and elevation data from any one of the radars listed below can be manually selected and utilized by the Launch Monitor Subsystem:

a. AN/FPS-16: Cape Canaveral

b. AN/FPS-16 (XN-2): Grand Bahama Island

c. AN/FPS-16: San Salvador Island

1.4.1.3 Burroughs—General-Electric Guidance System Computer

The guidance system, of which this computer is a part, tracks the vehicle as one of its functions. The computer has available in its computations position and velocity vectors describing the vehicle's trajectory, as well as a number of other parameters concerning its performance. The position and velocity vectors and a specified group of performance parameters will be made available to the Launch Monitor Subsystem.

1.4.1.4 Capsule Telemetry Receiver

The capsule telemetry receiver receives a great number of parameters from a transmitter in the capsule. These parameters concern the condition of the capsule occupant, the capsule environment, the status of certain equipment in the capsule, and the status of certain discrete events. The Launch Monitor Subsystem utilizes only the items concerning the status of certain capsule equipment and the status of certain discrete events, as inputs. These parameters are important in the computations that must be performed in the Goddard Computing Center and must therefore be transmitted from Cape Canaveral to Goddard. The remainder of the capsule telemetry data is displayed directly to the personnel in the Mercury Control Center.

1.4.1.5 Mercury Control Center

Personnel of the Mercury Control Center are capable of manually generating signals indicating certain functions they have performed, such as commanding an abort and overriding telemetry signals. These signals also serve as input data to the processing functions performed at the Goddard Computing Center.

1.4.1.6 Bermuda

The data sources from which inputs to the Bermuda IBM 709 computer are obtained are radar and telemetry equipments or the Control Center command and override functions. The data is similar to that provided by similar sources to the Goddard computers. The principal difference is that the Bermuda computer receives fewer data items and from fewer sources.

1.4.2 Overall Data Flow

This paragraph discusses the overall data flow. No attempt is made here to describe in detail each item of data, the number of bits of each quantity, or the frequency of transmitting data items. Later parts of this report cover such information in detail. Table 1-1 illustrates this data flow, showing sources and destinations of the various data quantities and indicating those signals that can be manually overridden.

The columns of table 1-1 indicate various locations and subdivisions of these locations. Under Cape Canaveral are listed four such subdivisions for radar (RDR), telemetry (TLM), the Burroughs—General-Electric Guidance System Computer, and the impact predictor 709 computer. The three subdivisions under Mercury Control Center indicate the type of unit where data is displayed—plot boards, digital displays, or strip chart. A data source or an override function shown under Digital Display (D/D) or Strip Chart (SC) indicates that a console associated with this display is capable of generating this data.

The Goddard column has only two subdivisions indicating that data is transmitted or received by high-speed (HS) data lines or low-speed (LS) data lines. The subdivisions under Bermuda are for radar, telemetry, the IBM 709 computer, plot board displays, or digital displays.

TABLE 1-1. LAUNCH MONITOR SUBSYSTEM DATA FLOW

	Cape Canaveral				Mercury Control Center			Goddard		Bermuda				
Quantity	RDR	TLM	B-GE	IP 709	PB	D/D	SC	LS	HS	RDR	TLM	709	PB	D/D
l,m,r (Azusa)	X			►										
R,A,E (AN/FPS-16)	X			►				►	►	X		►		
								◄				X		
Position vectors, X, Y, Z				X					►					
Velocity vectors, $\dot{X}$, $\dot{Y}$, $\dot{Z}$				X					►					
Elapsed time			X	X	►				►					
					◄				X					
Check sum, Σ			X	X					►					
Position vectors, ξ, η, ζ			X						►					
Velocity vectors, $\dot{\xi}$, $\dot{\eta}$, $\dot{\zeta}$			X						►					
Flags, δ_1, δ_2, δ_3, γ_n			X						►					
Booster engine cutoff (BECO)			X				►		►					
Sustainer engine cutoff (SECO)			X				►		►					
Go-no-go recommendation			X			►			►			X		►
						◄			X					
Liftoff		X	X			O			►					
Flight path angle deviation			X				►◄		X					
Velocity ratio deviation			X				►◄		X					
Yaw velocity error			X		►									
Time to go to SECO			X		►									
Predicted insertion altitude			X		►									
Inertial velocity			X		►◄				X					
Horizontal range			X		►◄				X					

TABLE 1-1. LAUNCH MONITOR SUBSYSTEM DATA FLOW (cont'd)

	Cape Canaveral				Mercury Control Center			Goddard		Bermuda				
Quantity	RDR	TLM	B-GE	IP 709	PB	D/D	SC	LS	HS	RDR	TLM	709	PB	D/D
Cross-range deviation			X		▶◀				X					
Altitude			X		▶◀				X			X		▶
Flight path angle			X		▶◀				X			X	▶	▶
Velocity ratio			X		▶◀				X			X	▶	▶
Capsule elapsed time		X							▶		X	▶		
Retrofire mechanism setting		X							▶		X	▶		
Staging		X				O			▶					
Escape tower separated		X				O			▶					
Escape tower rockets fired		X				O			▶					
Capsule separated from sustainer		X				O			▶		X	▶		O
1,2, or 3 posigrades fired		X				O			▶		X	▶		O
Retro sequence initiated		X				O			▶		X	▶		O
Acceleration		X			▶									
1,2, or 3 retrorockets fired		X				O			▶		X	▶		O
Data selection						X			▶					
Change displays												◀		X
Abort phase started						X			▶					
Orbit phase started						X			▶					
Longitude of perigee					◀				X					
Eccentricity					◀				X					
Impact point					◀	◀			X			X	▶	
Altitude of apogee					◀				X					
Inclination angle						◀			X					

TABLE 1-1. LAUNCH MONITOR SUBSYSTEM DATA FLOW (cont'd)

	Cape Canaveral				Mercury Control Center			Goddard		Bermuda				
Quantity	RDR	TLM	B-GE	IP 709	PB	D/D	SC	LS	HS	RDR	TLM	709	PB	D/D
Orbit capability						◄			X					
GMT to retrofire						◄			X			X		►
ECT to retrofire						◄			X			X		►
GMT of retrofire mechanism setting						◄			X					
Elapsed time since retrofire						◄			X					
Incremental capsule time to retrofire						◄			X					
Recovery area						◄			X			X		►
GMT to landing						◄			X					
Time until retrofire						◄			X					
Orbit No.						◄			X					
Time signals					◄	◄	◄		X					

LEGEND: X indicates source
► indicates destination
O indicates signal displayed here for override action if required

CHAPTER 2

DETAILED EQUIPMENT DESCRIPTION

SECTION 1

CAPE CANAVERAL EQUIPMENT

1.1 MERCURY CONTROL CENTER

Because the principal function of the Mercury Control Center (fig. 2-1) is to provide datà to the human operators and controllers, this paragraph first describes the equipment that presents computer-generated data for human observation (pars. 1.1.1 to 1.1.13). It then describes the path of data from receipt until it is thus displayed (pars. 1.1.14 to 1.1.17). Following this is a description of the equipment that receives telemetry and human decision information and transmits it from the Mercury Control Center (pars. 1.1.18 to 1.1.22).

1.1.1 Plot Board I (not IBM supplied)

Plot board I is an X, Y plotter with a plotting area of 30 by 30 inches. It has two carriages, each with two pens, and can therefore make two independent X vs Y plots. One of the pens of each carriage remains on the plot, except during large transitions, and plots the X vs Y variables. The other pen makes time marks as described in table 2-1, note 1. The time mark inputs are always IBM 7090 generated and are not switchable to B-GE. This plotter is used during the launch, abort, orbit, and re-entry phases. During the launch phase up to either the abort or orbit phase, it may be switched by the switch unit to receive IBM 7090 or B-GE generated data, since both furnish the same variables. During abort, orbit, and re-entry, it is switched by the switch unit to receive IBM 7090 data, since the B-GE computer does not make orbit or re-entry calculations. Table 2-1 shows the variables that are plotted. Figure 2-2 shows a physical representation of the displays.

1.1.2 Plot Board II (not IBM supplied)

Plot board II is an X, Y plotter, identical with plot board I. The second pen, on each of the two carriages, makes time marks as described in table 2-2, note 1. This plotter is used during all phases of a Mercury flight. During the launch phase, up to either the abort or orbit phase, it may be switched by the switch unit to receive IBM 7090 or B-GE generated data, since both furnish the same variables. During abort, orbit, and re-entry, it is switched by the switch unit to receive IBM 7090 data, since the B-GE computer does not make orbit or re-entry calculations. Table 2-2 shows the variables that are plotted. Figure 2-3 shows a physical representation of the displays.

1.1.3 Plot Board III (not IBM supplied)

Plot board III, identical with plot board I, makes IBM 7090 generated time marks (table 2-3, note 1) and is used during the launch and orbit phases. It has the following added capabilities: 175 seconds after liftoff, a switch or relay switches from the variables initially plotted to another set of variables. Since the above-mentioned variables are generated by the B-GE computer, this plotter is switched during launch to receive B-GE data. During orbit, it is switched to receive IBM 7090 data. (See table 2-3 and figs. 2-4 and 2-14.)

1.1.4 Plot Board IV (not IBM supplied)

Plot board IV, identical with plot board I, is used during all flight phases. The variables plotted are generated only by the IBM 7090, and, therefore, no provision is made to switch to other than IBM 7090 data. (See table 2-4 and fig. 2-5.)

1.1.5 Flight Dynamics Officer's Console (not IBM supplied)

This console contains digital (decimal) displays and lamp indicators as are physically represented in figure 2-6 and detailed in table 2-5. A go-no-go recommendation from B-GE data, or from IBM 7090 data, is selected by the switch unit. All other digital displays are generated from IBM 7090 data.

1.1.6 Retrofire Controller's Console (not IBM supplied)

This console contains digital (decimal) displays and lamp indicators as are physically represented in figure 2-7 and detailed in table 2-6. All displays are generated from IBM 7090 data.

1.1.7 Recovery Status Monitor Console (not IBM supplied)

This console contains decimal displays (table 2-7 and fig. 2-8). All displays are generated from IBM 7090 data.

1.1.8 Launch Vehicle Telemetry Monitor Console (not IBM supplied)

This console contains a strip chart recorder (table 2-8 and fig. 2-9). Displays of booster engine cutoff and of sustainer engine cutoff are generated from B-GE data.

1.1.9 Capsule Communicator's Console (not IBM supplied)

This console contains a decimal display for one value of elapsed capsule time of retrofire, computed (ECTRC). Three pushbuttons permit the selection of one of the three computer-generated values of ECTRC. (See table 2-9 and fig. 2-10.) Twelve telemetry events are also displayed here for override action, if required. Twelve switches control the override function on these events.

1.1.10 Wall Digital Display (not IBM supplied)

This display shows decimal displays (table 2-10 and fig. 2-11) generated from IBM 7090 data.

1.1.11 Wall Map Display (not IBM supplied)

This display shows two X vs Y locations on a large flat world map. It is not the marking type and therefore shows only the present value of the four variables. It is used during all phases of a Mercury flight (table 2-11 and fig. 2-12). All displays are generated from IBM 7090 data.

1.1.12 Data Quality Monitor

The data quality monitor is a 7- or 8- channel (pen) strip recorder with selectable paper speeds. One pen makes time marks, as described in table 2-12, note 1, for the launch phase. This recorder plots two variables from three sources: B-GE computer, B-GE data processed by the IBM 7090, and IP 709 or related radar data processed by the IBM 7090. Mounted on the recorder or on an adjacent console are the other lamp indicators shown in table 2-12 and figure 2-13. The four B-GE indicators tell the operator the quality of the B-GE generated data. The six plots of variables allow the operator to compare two like variables from the B-GE computer: B-GE data processed by the IBM 7090 and IP 709 or related radar data processed by the IBM 7090. The data source indicators are described in the following paragraph.

The operator has several controls and associated indicators available:

a. A 2-position switch telling the IBM 7090, at Goddard, to send data to the Mercury Control Center based on inputs from the B-GE complex or from the IP 709 complex; two indicators giving the switch position; two indicators, actuated by the data source bits from IBM 7090, giving the data source being used, for displays, by the IBM 7090. Thus, this group of four indicators shows the source selection and the confirmation of this selection. Two confirmation indicators lit, or neither lit, indicate malfunction.

b. A 2-position switch to select the data source (B-GE or IBM 7090) for plot boards I and II and four indicators to show selection and to confirm this selection. As stated in paragraphs 1.1.1 and 1.1.2, either B-GE or IBM 7090 can be selected during launch. However, IBM 7090 must be selected during abort, orbit, and re-entry.

c. A 2-position switch to select the data source (B-GE or IBM 7090) for plot board III and four indicators to show selection and to confirm this selection. As stated in paragraph 1.1.3, B-GE is selected during launch, IBM 7090 is selected during orbit.

d. A 2-position switch to select one of the two identical receiving registers (IBM 7090 data) to drive all displays not being driven by B-GE data, and the four indicators to show selection and to confirm this selection. This switch may normally be in either position and need be switched only if one of the receiving registers or its driving circuitry malfunctions.

e. A double-throw switch, with a center off position, to tell the IBM 7090 at Goddard which phase of the flight has started. The center off position indicates launch phase, one of the other positions indicates that the abort phase has started, and the remaining position indicates that the orbit phase has started. No switch is necessary or available to indicate re-entry. Two indicators show the switch position, other than center off. There are no indicators confirming these selections, however; this confirmation will be in the form of different displays being generated as is detailed in figure 2-13.

1.1.13 Digital-to-Analog Converters

Digital-to-analog converters at the Mercury Control Center (shown in figure 2-1) accept 10-bit quantities and generate a corresponding analog voltage, so that plot boards I, II, III, and IV, wall map display, and the data quality monitor display the plots as detailed in tables 2-1 to 2-4, 2-11, and 2-12.

1.1.14 Data Receivers (IBM 7090 Data)

As shown in table 2-13, four data receivers receive identical data from Goddard. These receivers each feed the binary data received to two comparators.

1.1.15 Comparator and Receiving Register

There are two (duplexed) of these units, each of which receives the binary data from the four data receivers. Since these units are identical, the following description applies to both.

The comparator and receiving register is capable of selecting data from three of the four data receivers. It compares the three binary bits received from the three receivers and accepts as valid the two that agree. It shifts this validated data into a register until the complete odd data frame is stored and transfers (parallel) this data into a storage register. It then shifts the even frame of validated data in until it is completely stored and transfers it into the storage register. (Table 2-13 shows the message format.) Data for digital displays is partly in the odd frame and partly in the even frame. All other IBM 7090 generated data is included in both frames. The storage register must therefore accommodate IBM 7090 generated data for all displays, this being more than the number of bits in the shift register. The outputs of the two comparator and receiving registers feed the switch unit.

1.1.16 Switch Unit

The switch unit accepts, in parallel, the outputs of the two comparator and receiving registers and, under control of the switches on the data quality monitor, selects one to feed all digital displays, and the D/A converters for the wall map display and plot board IV. At the same time it selects the same one to feed the relays that select B-GE or IBM 7090 data for plot boards I, II, and III. This unit, under data quality monitor control, also selects B-GE or IBM 7090 data to feed the go-no-go recommendation indicators on the flight dynamics officer's console, and the D/A converters for plot boards I and II, and independently makes a B-GE or IBM 7090 selection for the D/A converters for plot board III. (See figure 2-14 and tables 2-1 to 2-12 for details of switching.)

1.1.17 Simplex Receiving Register

The simplex receiving register receives data from the B-GE complex as shown in table 2-14. Some of this data directly feeds D/A converters for plot board III and the data quality monitor, and lamp indicator driving circuitry in the data quality monitor and missile telemetry monitor console. Other data is available to the switch unit, for selection, to feed the go-no-go recommendation indicators on the flight dynamics officer's console, and the D/A's for plot boards I, II, and III. Tables 2-1 to 2-12 and figure 2-14 show the data displayed and how it can be switched.

1.1.18 Telemetry Event Transmitting Buffer

Each duplex equipment in the telemetry event transmitting buffer receives capsule elapsed time and retrofire setting from the capsule via the telemetry receiver. Each receives other single-event and human decision data from the capsule communicator console and transmits it as follows: one of the duplexed buffers serially transmits data to the B-GE complex; the other, to the IP 709 complex. Either buffer is capable of driving both these outputs. (See table 2-15 for data transmitted.)

1.1.19 Operational Data Recorder ("A" Simulator)

The operational data recorder is a magnetic tape unit and provides for recording and playing back tone burst signals from seven data transmission circuits. The signals recorded are the input signals to the four data receivers and to the simplex receiving register and the two outputs from the telemetry event transmitting buffer at the Mercury Control Center. This unit is used for operational recording and for open loop simulation.

1.1.20 Trajectory Tape Playback Simulator ("B" Simulator)

The trajectory tape playback simulator is used for closed loop simulation. It consists of a magnetic tape unit capable of reading digital magnetic tapes prepared by an IBM 709 computer, and a flight flag register. The outputs of the magnetic tape unit are signals that simulate the outputs of the impact predictor 709 computer and of the Burroughs—General-Electric guidance computer. In addition, it provides control signals to permit the interleaving of telemetry event data with the IP 709 data message and with the B-GE data message, as detailed in figures 2-15 to 2-17. It also provides an output of up to 10 discrete flight flag signals to the flight flag register.

The flight flag register provides latching dry relay contacts for these 10 signals. A patchboard arrangement permits these signals to be used in a flexible manner.

1.1.21 Interface Junction Box

The interface junction box is used to interconnect the four data receivers, the telemetry event transmitting buffer, and the 128-bit receiving register with the data transmission circuits entering and leaving the Mercury Control Center. In addition, it interconnects the telemetry event transmitting buffer with the telemetry receiver, the Stromberg-Carlson signal distribution panel, and the digital junction box. It also provides the ability to change interconnections.

1.1.22 Digital Junction Box

The digital junction box is used to interconnect the digital outputs of the 128-bit receiving register and the comparator and receiving registers, as selected by the switch unit, with the digital-to-analog converters, the data quality monitor, and the Stromberg-Carlson signal distribution panel. The ability to change interconnections is also provided.

1.2 BURROUGHS—GENERAL-ELECTRIC COMPLEX

1.2.1 High-Speed Buffer and Retransmitter

The high-speed input buffer and dual data retransmitter accepts data from two sources, buffers the data, and retransmits data, at 1000 bits per second, to two destinations. The time between the start of transmission is under B-GE computer control and is 500 ± 100 milliseconds. (See fig. 2-18.)

1.2.1.1 Inputs

The high-speed buffer and retransmitter accepts 24-bit parallel data transfers from the B-GE computer. The data transferred is shown in table 2-16.

The output quantities are transferred to the high-speed input buffer and dual data retransmitter as a series of 21 parallel transfers of 24 bits each. Bit 0 is the sign bit, and bit 23 is the least significant bit.

This unit also accepts the serial transfer of the data, detailed in table 2-15, from the telemetry event transmitting buffer, Mercury Control Center.

1.2.1.2 Outputs

The high-speed buffer and retransmitter transmits the data received from B-GE and the Mercury Control Center as follows. It serially transmits selected data, with duplexed transmitters and over two lines, to Goddard, as detailed in figure 2-15. It serially transmits selected data over one line to the Mercury Control Center, as detailed in table 2-14.

1.2.2 Operational Data Recorder

The operational data recorder is a magnetic tape unit for recording and playing back tone burst signals from four data transmission circuits. The signals recorded are the input signals to the B-GE high-speed buffer and retransmitter from the telemetry event transmitting buffer at the Mercury Control Center, and the output signals from the B-GE high-speed buffer and retransmitter to the 128-bit receiving register at the Mercury Control Center and to two data receivers at Goddard.

1.3 IMPACT PREDICTOR 709 COMPLEX

1.3.1 High-Speed Buffer and Retransmitter

The high-speed input buffer and dual data retransmitter simultaneously accepts two inputs: one from the Mercury Control Center telemetry event transmitting buffer, the other from either the IBM 709 computer or one of three radars. It retransmits the data, at 1000 bits per second, to Goddard. The time between the start of transmission is approximately 400 milliseconds. (See fig. 2-19.)

1.3.1.1 Inputs

The high-speed buffer and retransmitter accepts the serial transfer of the data, detailed in table 2-15, from the Mercury Control Center telemetry event transmitting buffer. It also accepts data from either the IBM 709, the Cape Canaveral AN/FPS-16, the Grand Bahama AN/FPS-16, or the San Salvadore AN/FPS-16. These inputs are manually selectable at this unit. This unit accepts 36-bit parallel transfers from the IBM 709, as detailed in table 2-17. Words 2 through 8 from the Impact Predictor 709 Computer are transmitted to the high-speed retransmitter at 0.4-second intervals in the format shown in table 2-17. Each word is 36-bit floating-point mode: sign, bits 1 through 8 - characteristic; bits 9 through 35 - fraction.

It also accepts serial data transfers from the selected radar, as detailed in table 2-18. Radar data from AN/FPS-16 radars consists of range, azimuth, and elevation values. This data is transmitted from the radar in serial fashion interleaved with synchronizing bits as indicated in table 2-18.

1.3.1.2 Outputs

This unit serially transmits all data, with duplexed transmitters and over two lines, to Goddard. Figures 2-16 and 2-17 detail data transmitted when IP-709 data is being used and when raw radar is being used.

1.3.2 Operational Data Recorder

The operational data recorder is a magnetic tape unit for recording and playing back tone burst signals from three data transmission circuits. The signals recorded are the input signals to the IP-709 high-speed buffer and retransmitter from the telemetry event transmitting buffer at the Mercury Control Center, and the output signals of the IP-709 high-speed buffer and re-transmitter to two data receivers at Goddard.

SECTION 2

GODDARD COMPUTER COMPLEX

Since the IBM 709 Data Processing Systems are adequately described in other documents, this paragraph describes only the peripheral equipment that is part of the Launch Monitor Subsystem. (See fig. 2-20.)

2.1 HIGH-SPEED DATA RECEIVERS

Two receivers accept the serial transmission of data from the B-GE complex, and two receivers accept data from the IP 709 complex, as detailed in figures 2-15 and 2-16. Each receiver performs as follows.

It buffers the data received serially until eight bits are received and then makes the eight bits available to a subchannel of the IBM 7090 data communications channel. The IBM 7090 immediately accepts the data (8-bit parallel transfer) so that the receiver is able to accept data continually at 1000 bits per second. In this manner, duplicate frames of data from the B-GE complex and duplicate frames of data from the IP 709 complex are available to the IBM 7090. Thus, if errors are introduced by transmission from Cape Canaveral, the data may be discarded. (See figures 2-15 and 2-16 for details of the data received.)

2.2 DIGITAL-TO-ANALOG CONVERTERS AND PLOT BOARDS

Two plot boards at Goddard are each driven by four D/A converter channels. Each plot board is an X, Y plotter with a plotting area of 30 x 30 inches. It has two carriages and can therefore make two independent X vs Y plots. One of the pens on each carriage remains on the plot, except during large transitions. Each plot board and its associated D/A converters normally receive data from one IBM 7090 computer. The capability of switching the D/A converter inputs so that each plot board receives data from the alternate computer is controlled from the output status console. Each computer, through its DCC, serially supplies 48 bits to the shift registers in the D/A as is detailed in table 2-19. After the 48-bit transfer, the data is transferred to a storage register which drives the D/A's and plot board. Thus each plot board displays two X vs Y plots.

2.3 OUTPUT STATUS CONSOLE

The output status console presents, for each computer, eight lamp indicators and an audible alarm, indicating the quality of each computer's output data.

These indicators and the plots enable an operator to determine which computer should supply data to the Mercury Control Center and to teletype transmitters. The switch that controls this output selection and the switch that controls the interchange of plot boards and computers are also on this console.

2.3.1 Inputs

The output status console receives eight parallel inputs from each IBM 7090 RTC (16 total). Seven of these eight inputs, when a 1, light indicators; the eighth also lights an indicator and initiates an audible alarm. The audible alarm can be reset by the operator; however, only the computer can change the visual indications.

2.3.2 Control and Associated Indicators

A 2-position switch on this console controls the output switch unit and thereby determines which IBM 7090 furnishes data to the Mercury Control Center and teletype transmitters. Four indicators are associated with this switch: two indicate the selection made, and two, controlled by the output switch unit, confirm the selection. A second 2-position switch controls the normal or crossed connection of plot boards and computers. Two associated indicators are used to indicate this selection.

2.4 OUTPUT SWITCH UNIT

This unit, under control of the output status console, selects which IBM 7090 furnishes output data.

2.4.1 Inputs

The output switch unit accepts serial data from the selected IBM 7090 DCC and connects this data line to all four high-speed data transmitters for transmission to the Mercury Control Center, Cape Canaveral. It also accepts teletype data from the selected IBM 7090 and connects these data lines to teletype distributor for outputs 1-8; it likewise connects other data lines to teletype distributor for outputs 9-16.

2.4.2 Control of Output Switch Unit

The output switch unit operates under control of the 2-position switch on the output status console. The output switch unit controls two indicators on that console, as described in paragraph 2.3.2 .

2.5 DATA TRANSMITTERS

The four data transmitters at Goddard each serially transmit data to the Mercury Control Center, Cape Canaveral, at 1000 bits per second. The data transmitted is detailed in table 2-13. Each transmitter transmits the same data. An odd data frame, followed by an even data frame, is transmitted every second during launch and abort, five times a minute during orbit, and 10 times a minute during re-entry. The receipt and display of this data is described in paragraph 1.1.

2.6 OPERATIONAL DATA RECORDER

The operational data recorder is a magnetic tape unit for recording and playing back tone burst signals from seven data transmission circuits. The signals recorded consist of the input signals to the four data receivers from the B-GE high-speed buffer and retransmitter and from the IP-709 high-speed buffer and retransmitter, and the output signals from three of the four data transmitters.

SECTION 3

BERMUDA COMPUTER COMPLEX

Since the IBM 709 Data Processing System is adequately described in other documents, this paragraph describes only the peripheral equipment that is part of the Launch Monitor Subsystem. (See fig. 2-21.)

3.1 HIGH-SPEED DATA RECEIVERS (not IBM supplied)

Capsule position data, during launch, abort, and orbit, is received from an AN/FPS-16 radar and a Verlort radar via this unit. The data received is so synchronized that corresponding 8-bit words from each radar are simultaneously accepted by the IBM 709 data communications channel. The data received is detailed in figure 2-22.

3.2 TELEMETRY EVENT BUFFER (not IBM supplied)

Telemetry time and single event data and human decision data from Bermuda are received by the IBM 709 DCC from the telemetry event buffer. The format detailed in table 2-20 constitutes a complete telemetry event data message. Transmission of this message into the data communications channel is on demand from the 709. The first bit of each quantity in capsule elapsed time and retrofire mechanism setting is the most significant bit.

3.3 TRANSFER REGISTER AND DIGITAL-TO-ANALOG CONVERTER

The shift registers of the transfer register and the D/A converter are connected end to end. The IBM 709 DCC serially supplies 96 bits to this combined register. The 96 bits of the odd frame are then transferred (parallel) to storage registers. Then, the IBM 709 serially supplies the 96 bits of even frame data, which are also transferred to storage registers. (See table 2-21 for details of the data transferred.) Data for digital displays is partly in the odd frame and partly in the even frame; plot board I data is included in both frames. Therefore, the storage register in the D/A converter need store only 40 bits; the transfer register's storage register must accommodate data for all digital displays. A data frame is initiated approximately every 500 milliseconds; first odd, then even. This data is available during launch, abort, orbit, and re-entry.

3.4 PLOT BOARD I (not IBM supplied)

This 30 x 30 inch X, Y plotter plots the variables, as represented and detailed in figure 2-23 and table 2-22. It is controlled by the four analog inputs from the D/A converter (paragraph 2.3.3).

3.5 FLIGHT DYNAMICS OFFICER'S CONSOLE (not IBM supplied)

The flight dynamics officer's console displays decimal information and includes two lamp indicators, GO and NO GO. The displays are driven by the storage registers in the transfer register. Figure 2-24 and table 2-23 show representation of displays and details of the display quantities.

3.6 OUTPUT STATUS CONSOLE

The output status console presents eight lamp indicators and an audible alarm, indicating the quality of the IBM 709 output data. This console receives eight parallel inputs from the IBM 709. Seven of these inputs, when a 1, light indicators; the eighth also lights an indicator and initiates an audible alarm. The audible alarm can be reset by the operator; however, only the computer can change the visual indications.

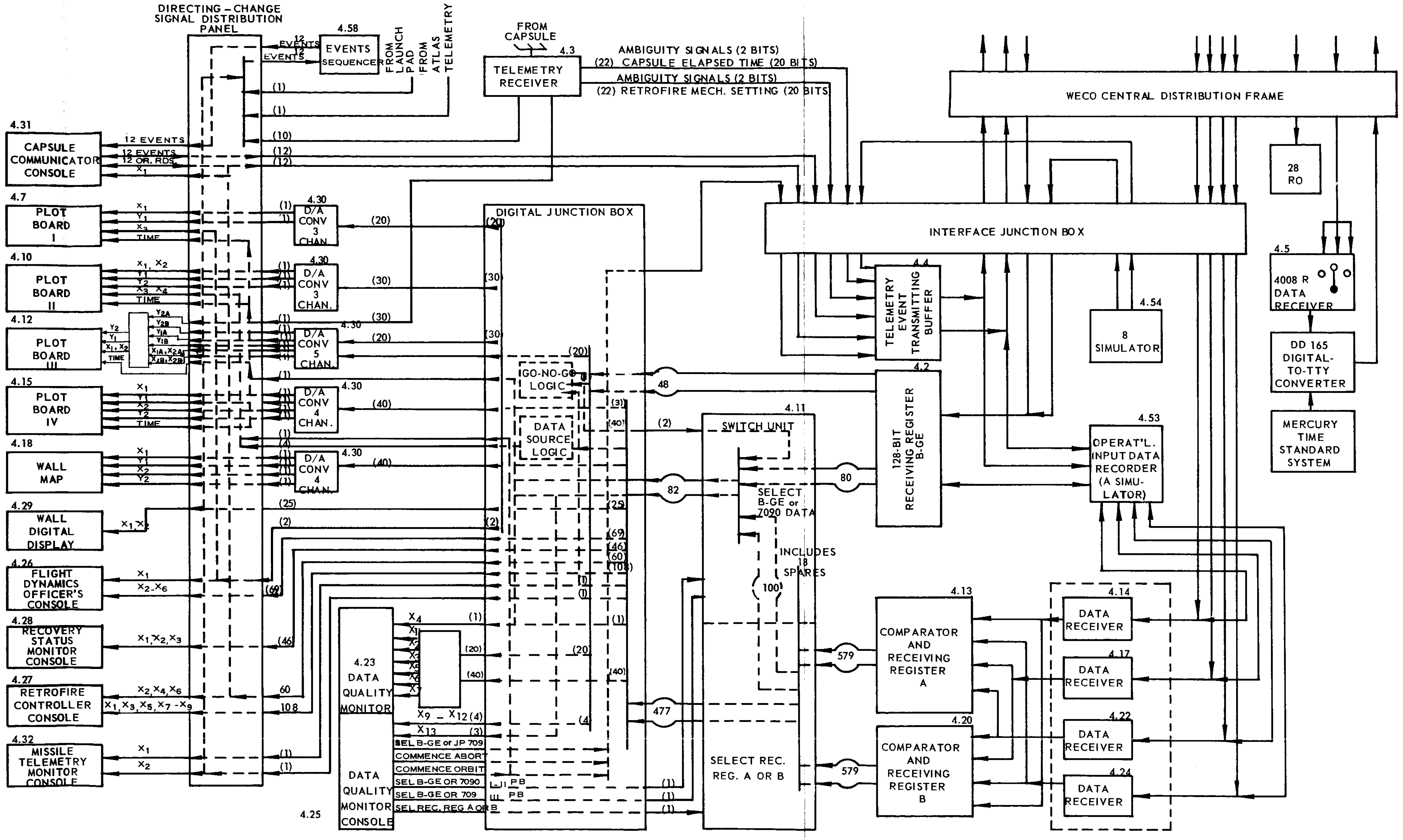


FIGURE 2-1. MERCURY CONTROL CENTER, SYSTEM DIAGRAM

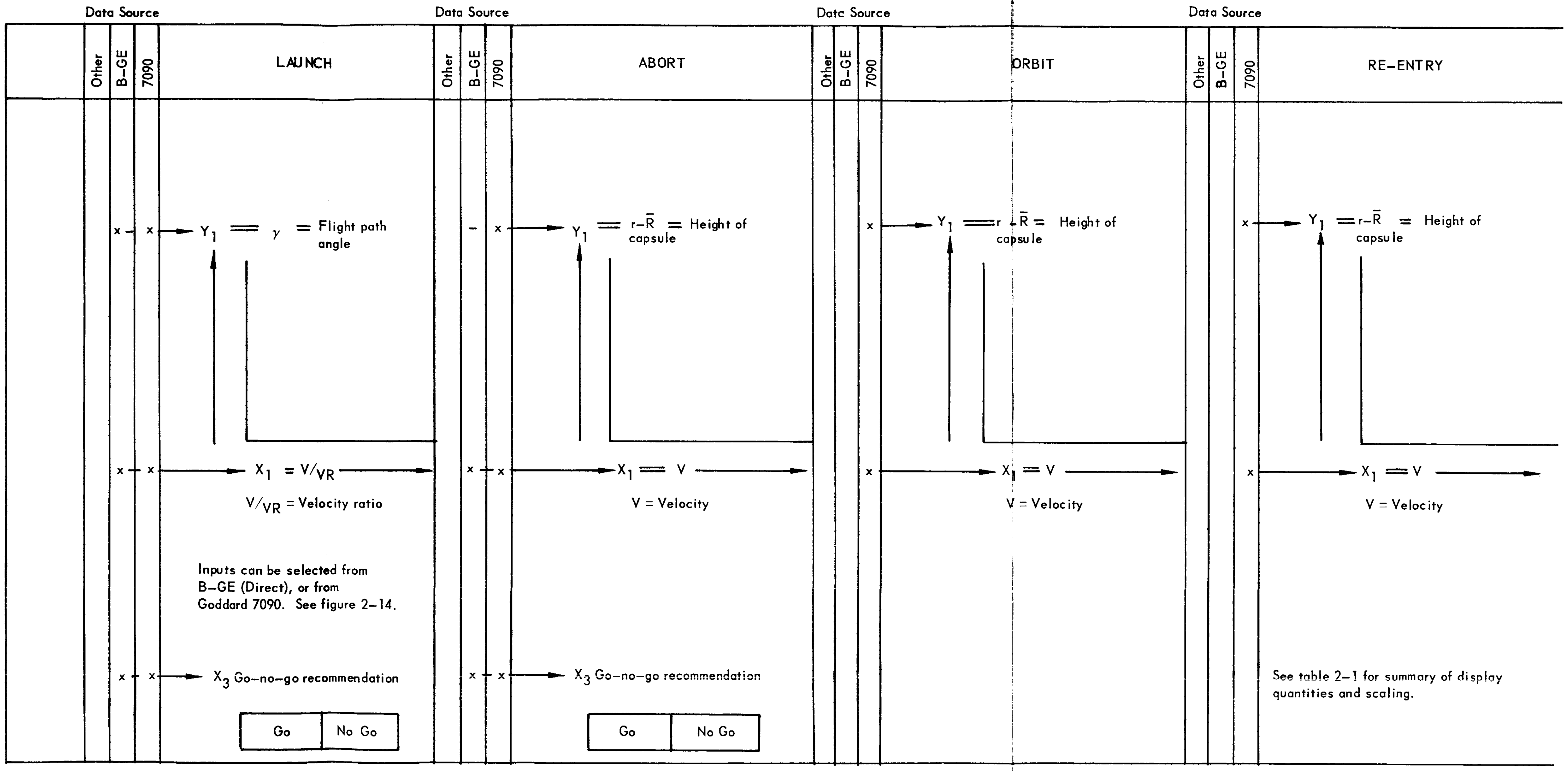


FIGURE 2-2. PLOT BOARD 1 (MCC), REPRESENTATION OF DISPLAYS

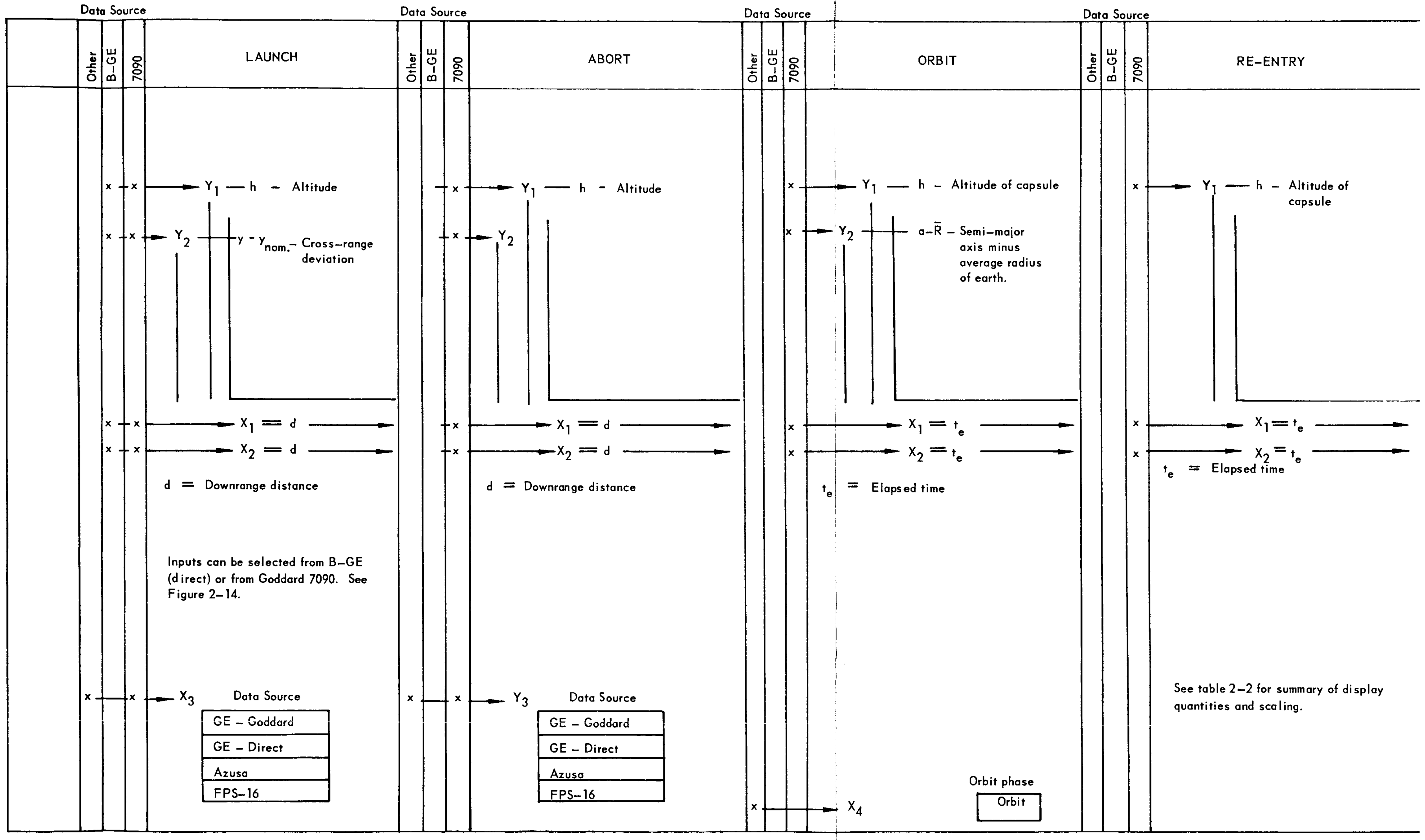


FIGURE 2-3. PLOT BOARD II (MCC), REPRESENTATION OF DISPLAYS

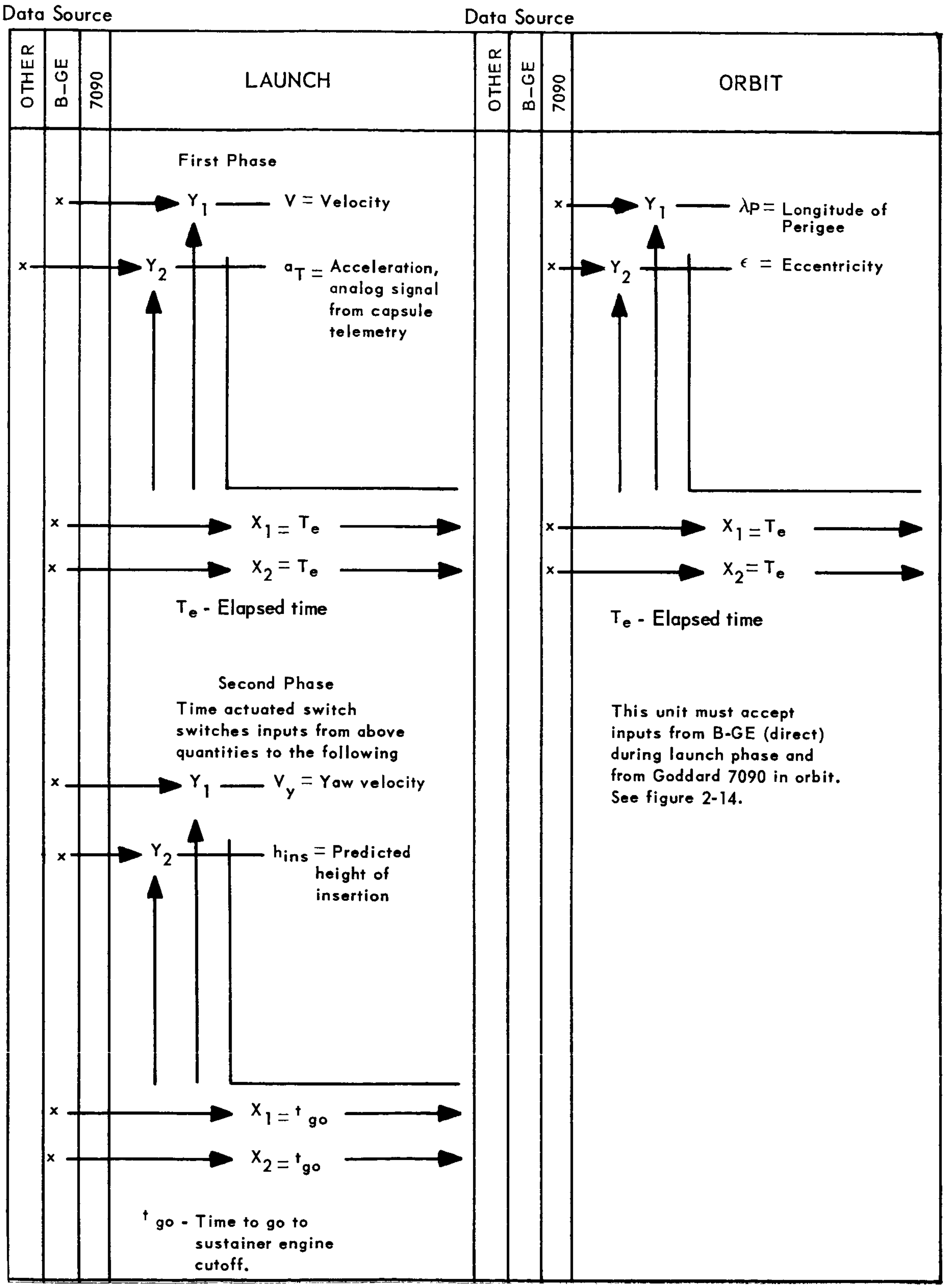


FIGURE 2-4. PLOT BOARD III (MCC), REPRESENTATION OF DISPLAYS

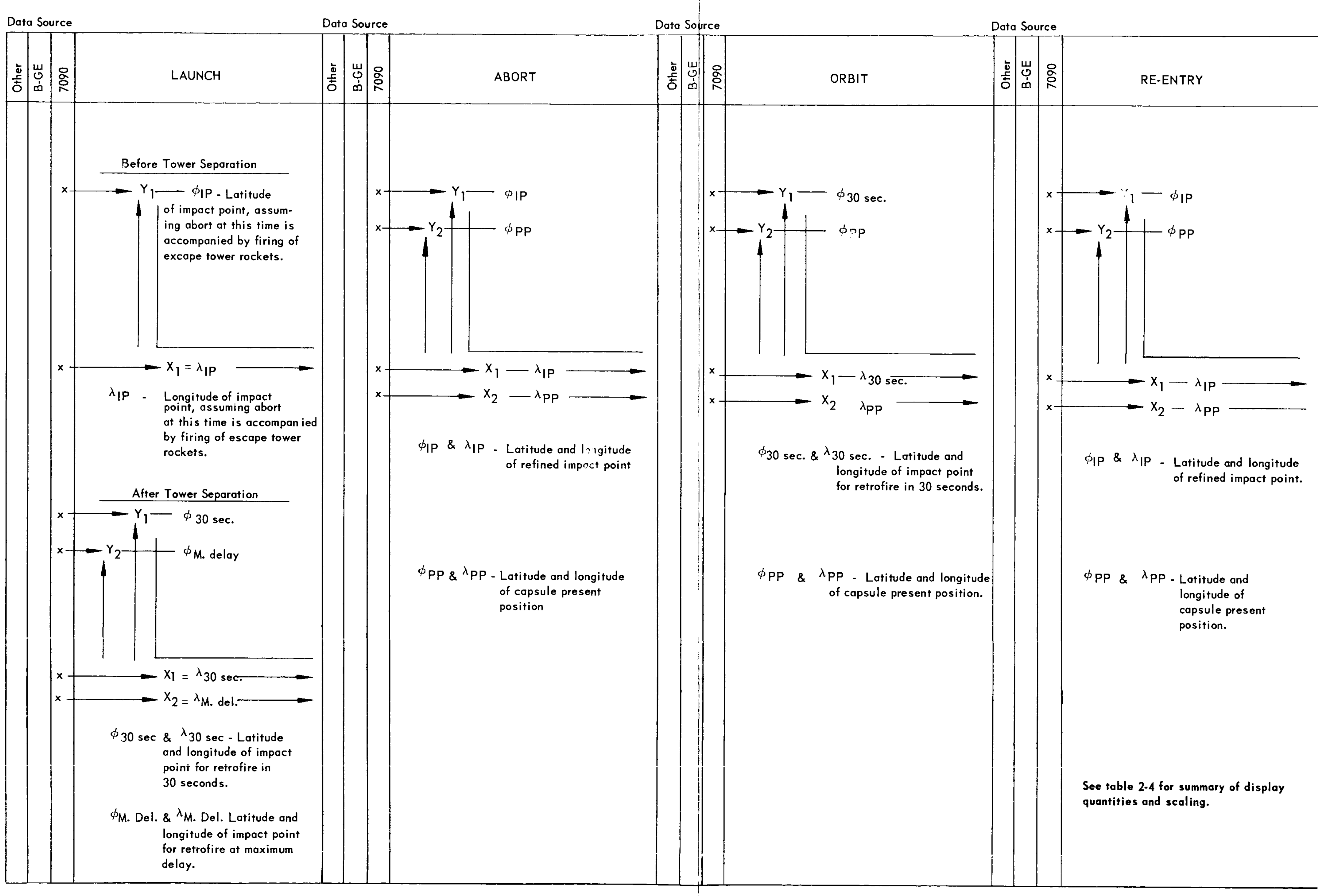


FIGURE 2-5. PLOT BOARD IV (MCC), REPRESENTATION OF DISPLAYS

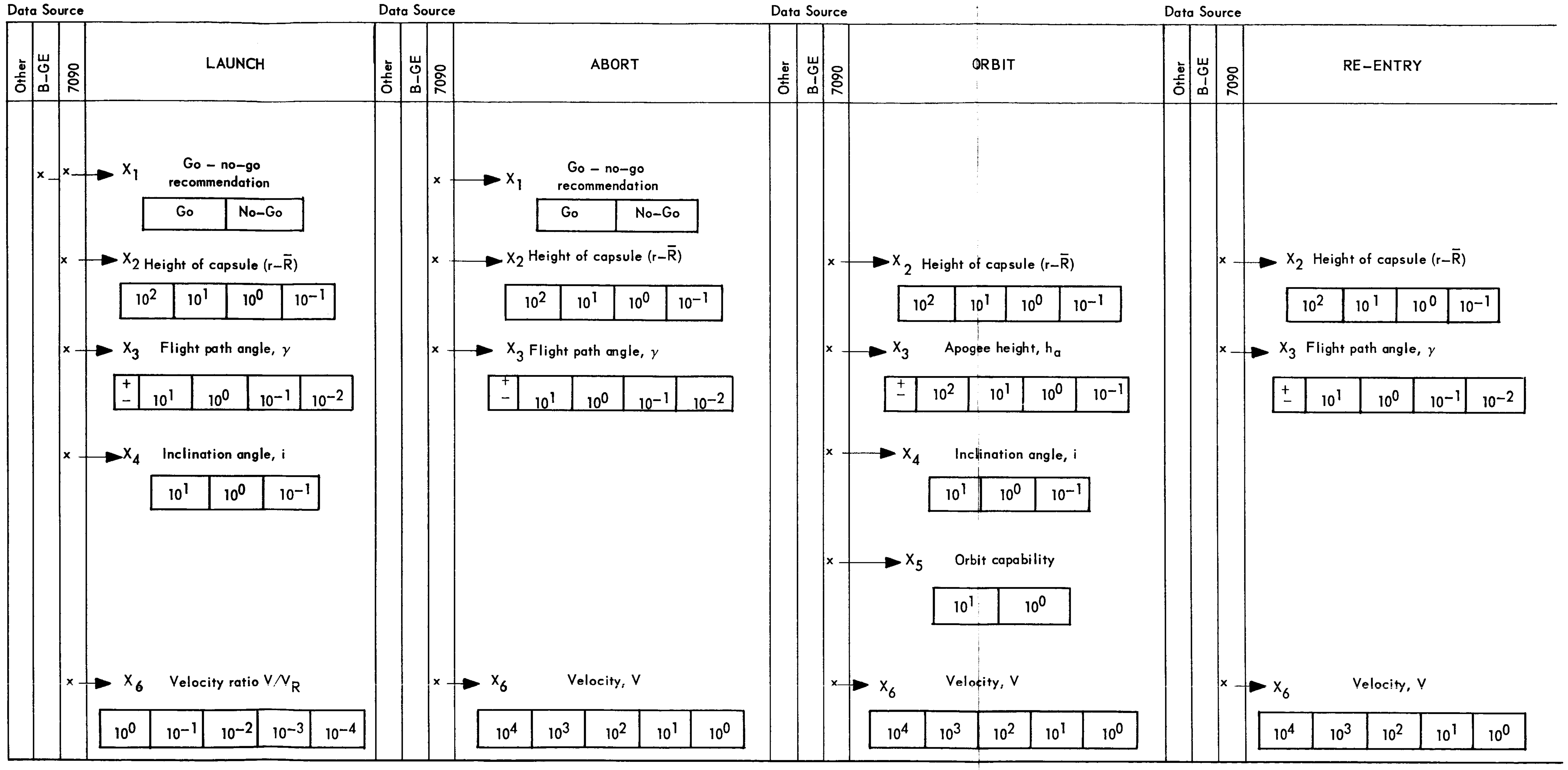


FIGURE 2-6. FLIGHT DYNAMICS OFFICER'S CONSOLE (MCC), REPRESENTATION OF DISPLAYS

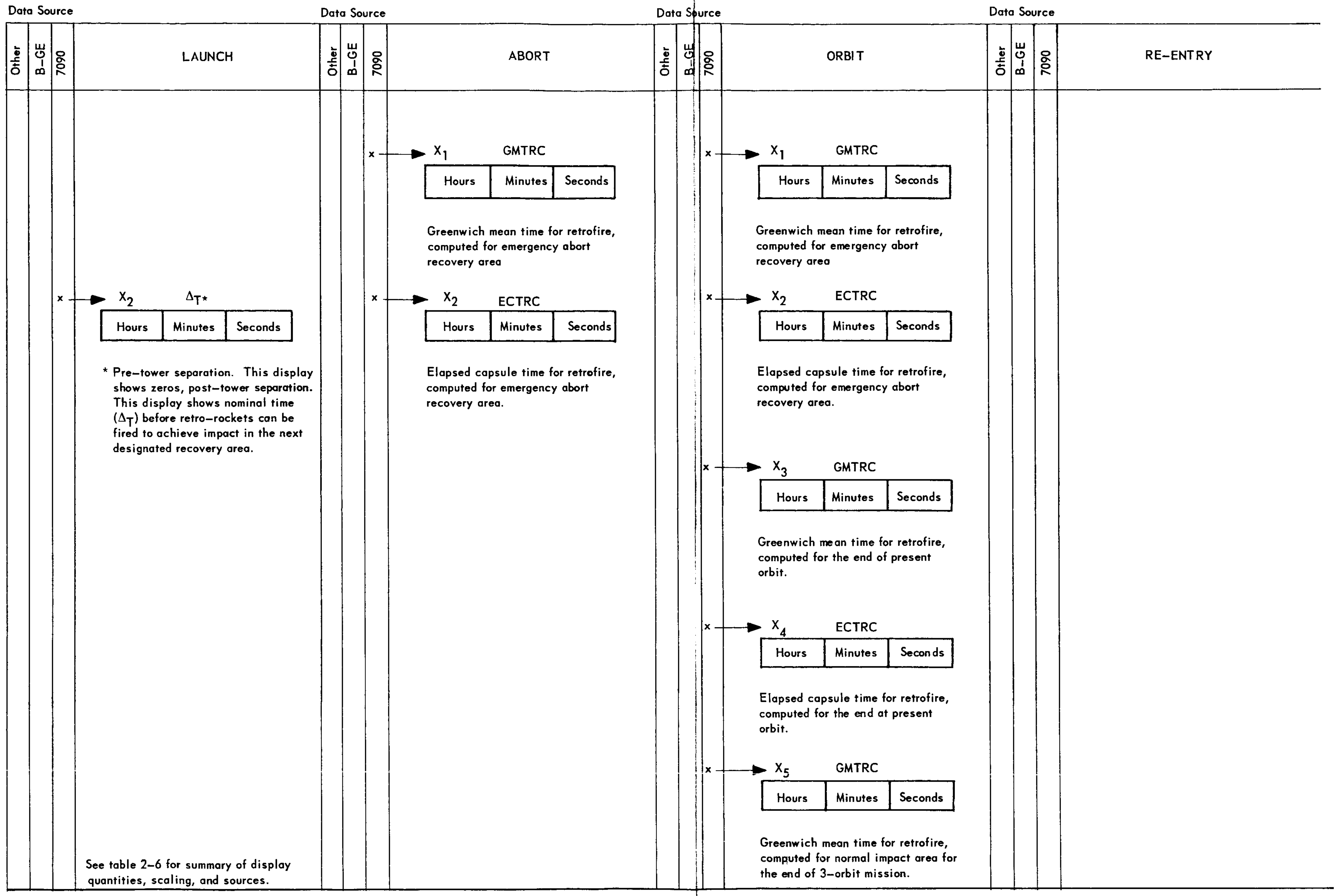


FIGURE 2-7. RETROFIRE CONTROLLER'S CONSOLE (MCC), REPRESENTATION OF DISPLAYS (SHEET 1 OF 2)

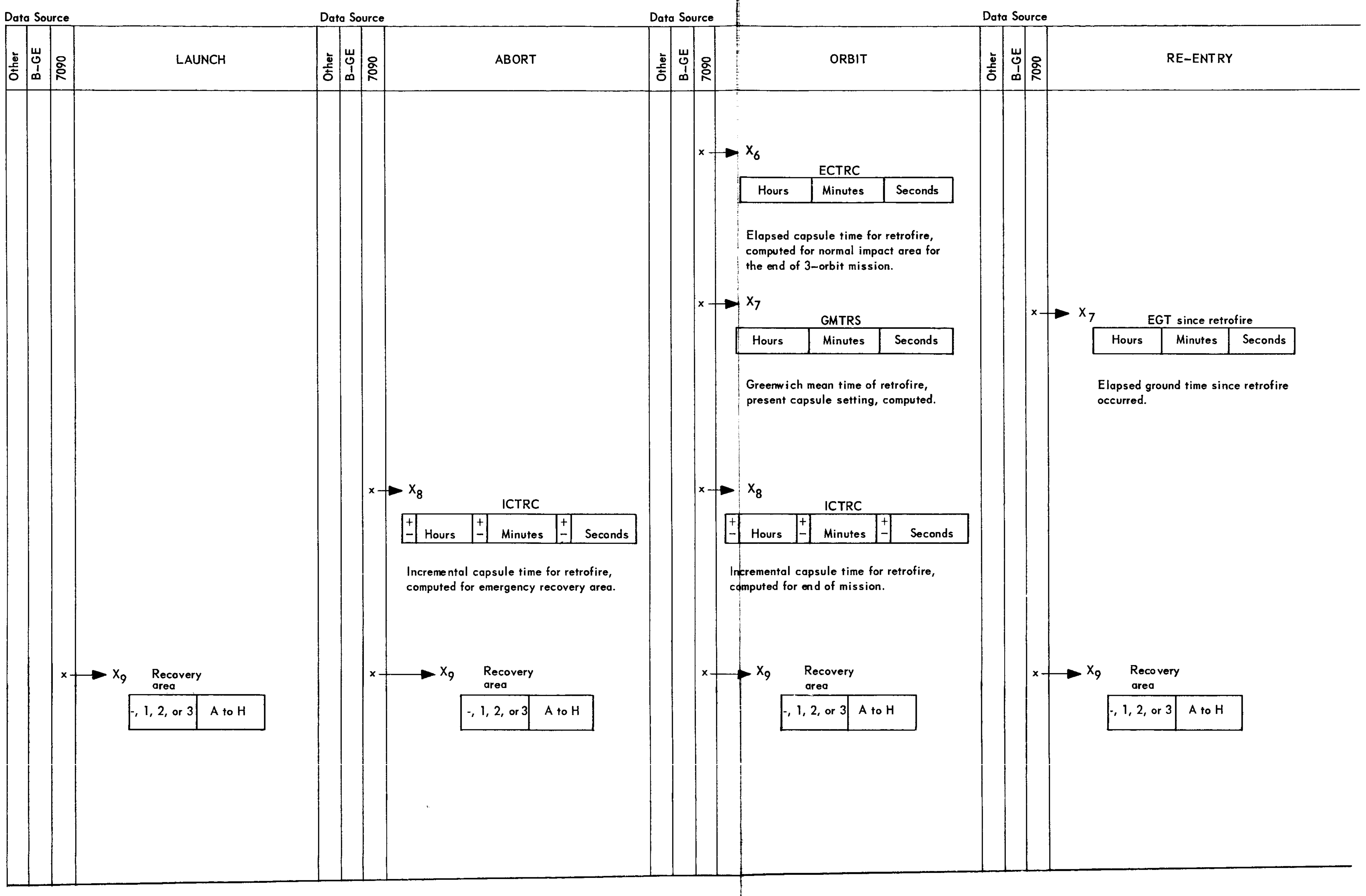


FIGURE 2-7. RETROFIRE CONTROLLER'S CONSOLE (MCC), REPRESENTATION OF DISPLAYS (SHEET 2 OF 2)

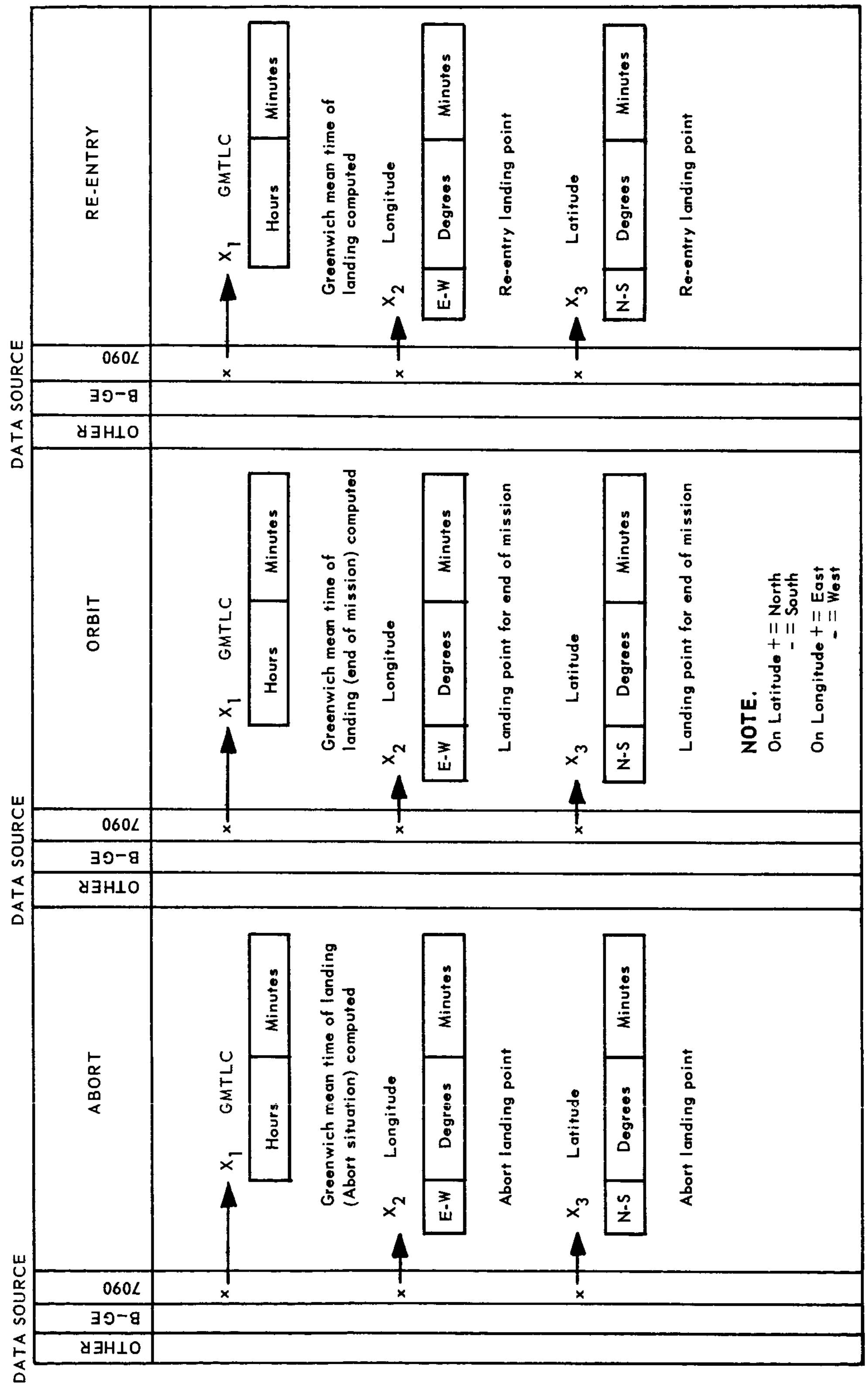


FIGURE 2-8. RECOVERY STATUS MONITOR CONSOLE (MCC), REPRESENTATION OF DISPLAYS

Data Source

Other	B-GE	7090	LAUNCH
	x		→ X_1 BECO (strip chart) Booster engine cutoff
	x		→ X_2 SECO (strip chart) Sustainer engine cutoff
			See table 2-8 for summary of display quantities, scaling, and sources.

FIGURE 2-9. LAUNCH VEHICLE TELEMETRY MONITOR CONSOLE (MCC), REPRESENTATION OF DISPLAYS

Data Source

Other	B-GE	7090	ABORT
		x	→ X_1 Desired Retrosetting Hours | Minutes | Seconds 1 | 2 | 3 Pushbuttons 1, 2, and 3 select one of the following quantities for display: 1. ECTRC – Elapsed capsule time for retrofire, computed for emergency abort recovery area. 2. No data available for display. 3. No data available for display. See table 2-9 for summary of display quantities, scaling, and sources.

Data Source

Other	B-GE	7090	ORBIT
		x	→ X_1 Desired Retrosetting Hours | Minutes | Seconds 1 | 2 | 3 Pushbuttons 1, 2, and 3 select one of the following quantities for display: 1. ECTRC – Elapsed capsule time for retrofire, computed for emergency abort recovery area. 2. ECTRC – Elapsed capsule time for retrofire, computed for the end of the present orbit. 3. ECTRC – Elapsed capsule time for retrofire, computed for normal impact area for the end of 3-orbit mission.

FIGURE 2-10. CAPSULE COMMUNICATOR'S CONSOLE (MCC), REPRESENTATION OF DISPLAYS

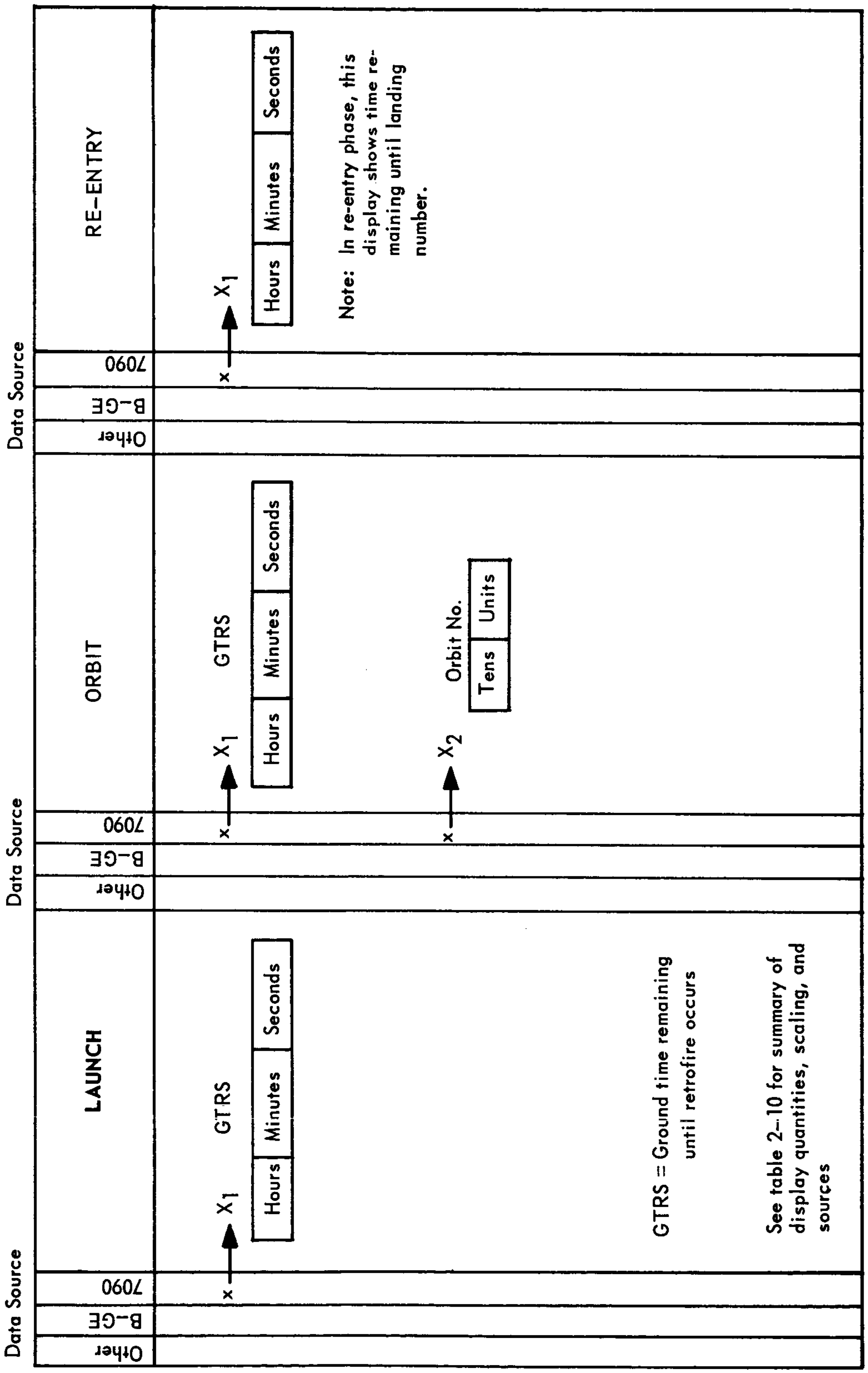


FIGURE 2-11. REPRESENTATION OF WALL DIGITAL DISPLAYS (MCC)

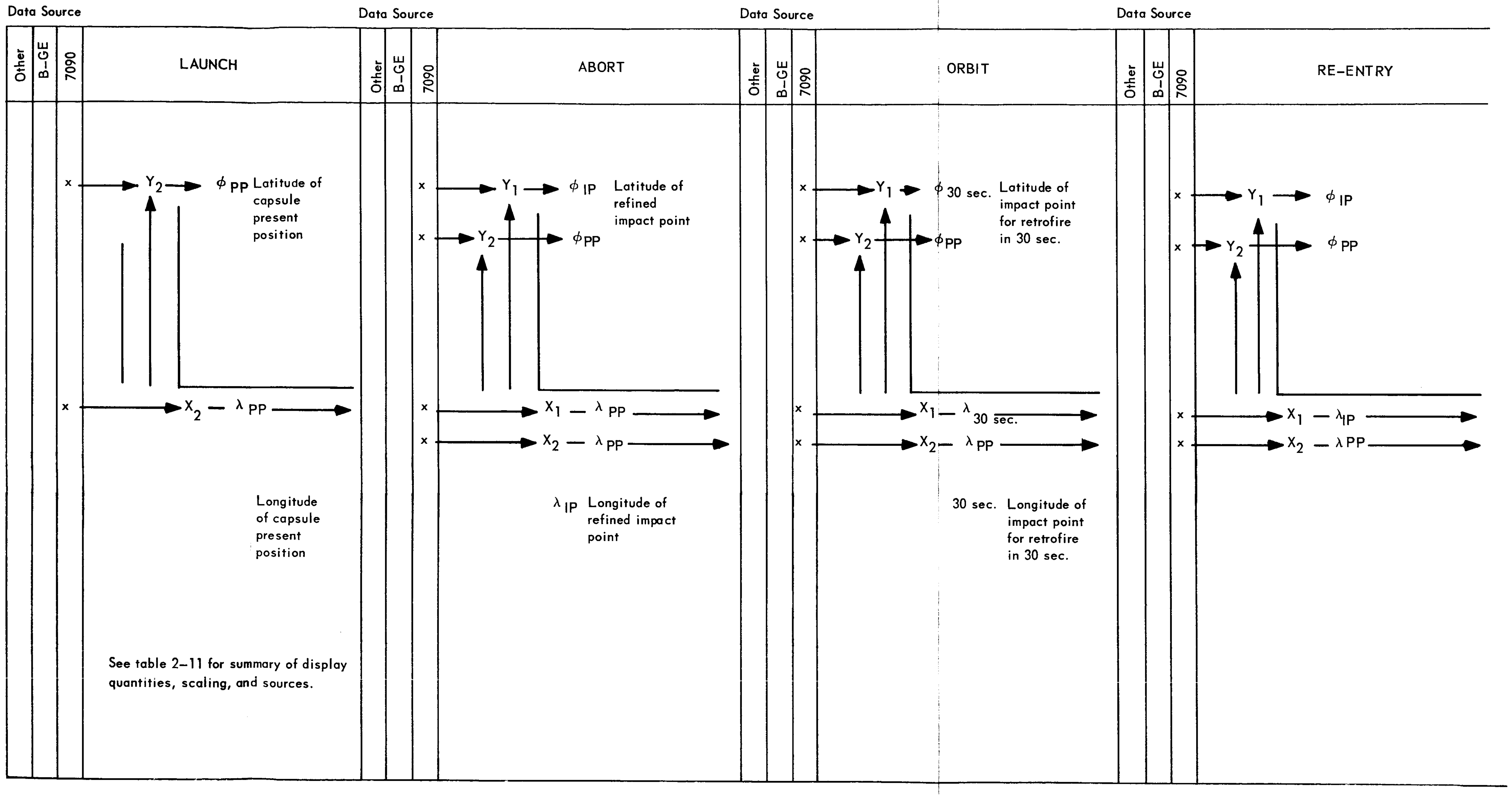


FIGURE 2-12. REPRESENTATION OF WALL MAP DISPLAYS (MCC)

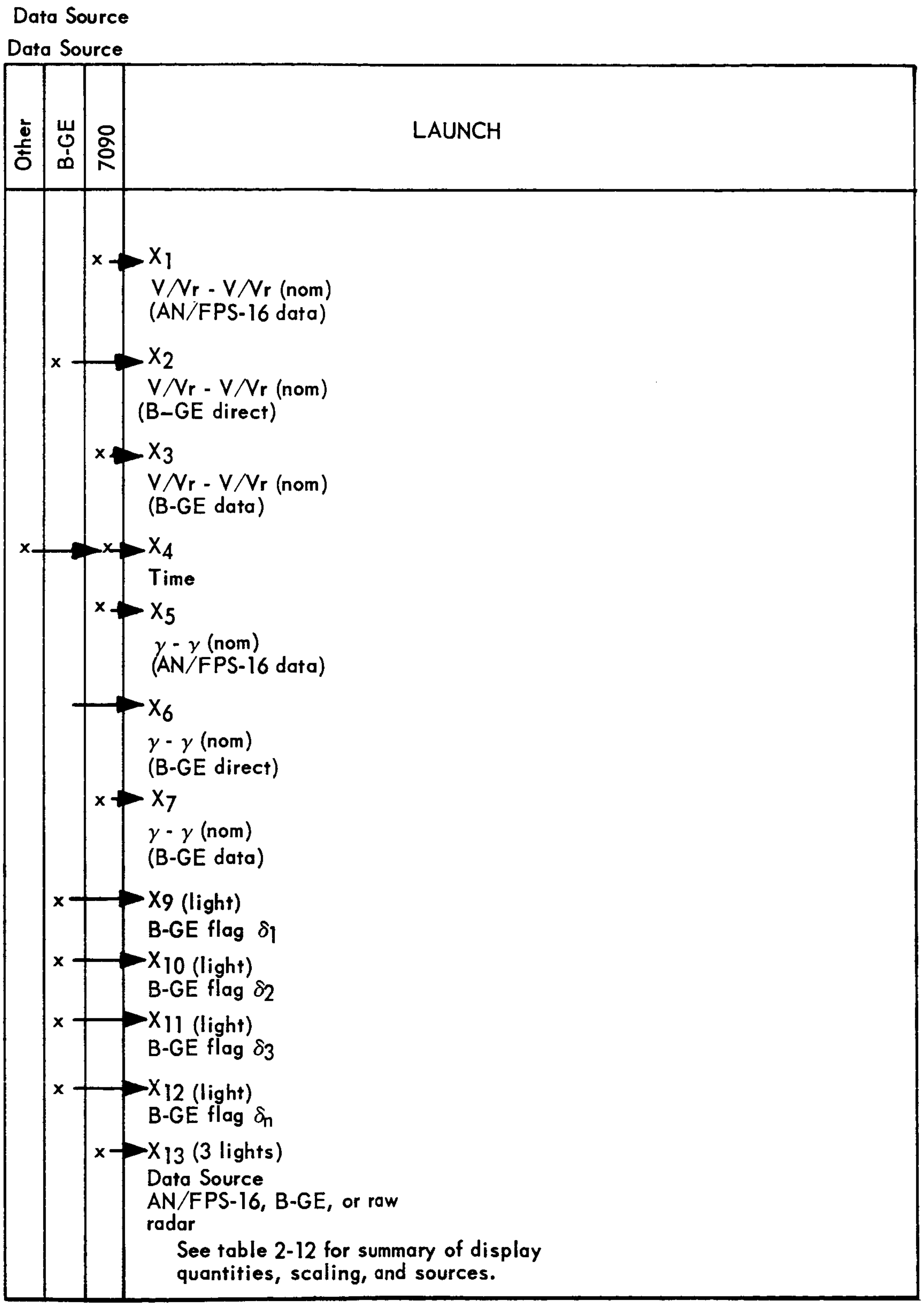


FIGURE 2-13. DATA QUALITY MONITOR (MCC), REPRESENTATION OF DISPLAYS

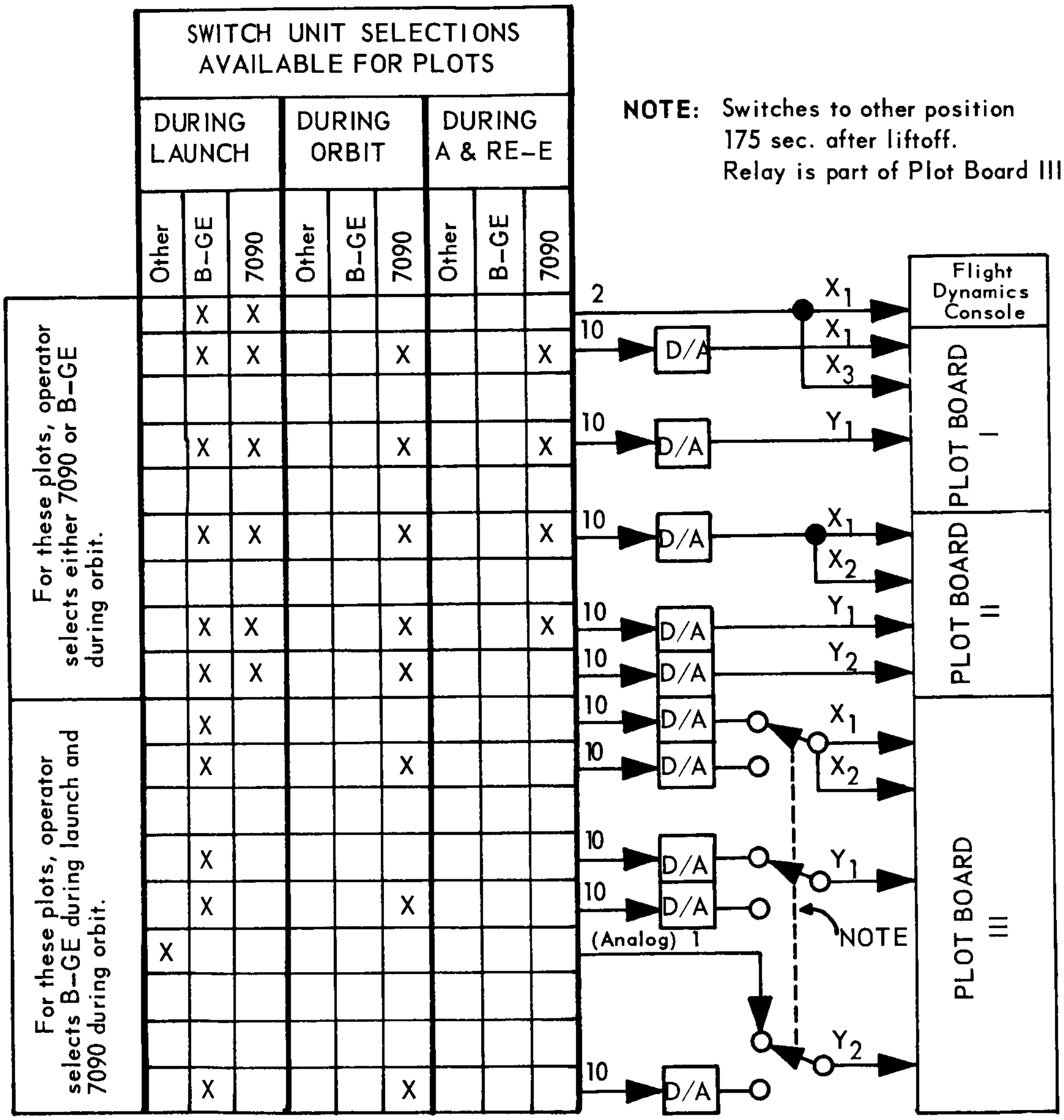


FIGURE 2-14. DATA SOURCE SELECTION ACCOMPLISHED WITH SWITCH UNIT, MERCURY CONTROL CENTER

8–Bit Word Transfers from Data Receiver
First Subframe

Word			
1	1	Telemetry	8
2	9	Telemetry	16
3	17	Telemetry	24
4	25	Telemetry	32
5	33	Telemetry	40
6	41	Telemetry	48
7	49	Telemetry	56
8	57	Telemetry	64
9	65	Telemetry	72
10	1	Discrete Word	8
11	1	G	8
12	9	G	16
13	17	G	24
14	1	H	8
15	9	H	16
16	17	H	24
17	1	J	8
18	9	J	16
19	17	J	24
20	1	K	8
21	9	K	16
22	17	K	24
23	1 1 1	1 1 1	1 1
24	0 0 0	1 ID*	5

8–Bit Word Transfers from Data Receiver
Second Subframe

Word			
1	1	L	8
2	9	L	16
3	17	L	24
4	1	M	8
5	9	M	16
6	17	M	24
7	1	N	8
8	9	N	16
9	17	N	24
10	1	Checksum	8
11	9	Checksum	16
12	17	Checksum	24
13	1 1 1	1 1 1	1 1
14	1 1 1	1 1 1	1 1
15	1 1 1	1 1 1	1 1
16	1 1 1	1 1 1	1 1
17	1 1 1	1 1 1	1 1
18	1 1 1	1 1 1	1 1
19	1 1 1	1 1 1	1 1
20	1 1 1	1 1 1	1 1
21	1 1 1	1 1 1	1 1
22	1 1 1	1 1 1	1 1
23	1 1 1	1 1 1	1 1
24	0 0 0	1 ID*	5

The above constitutes a complete message frame and is transmitted with an interval of 500 ± 100 milliseconds between the start of one message and the start of the next message. Each subframe consists of 192 serial bits preceded by a sync signal. The quantities represented by G, H, J, K, L, M, and N are restricted information and are specified in other documents.

* See Note 1 for makeup of ID word.

See Note 2 for format of bits 1 to 72 of first subframe in absence telemetry data and Note 3 for format in absence of quantities G, H, J, K, L, M, and N.

See table 2–15 for format of telemetry data.

FIGURE 2–15. BURROUGHS-GE DATA, CAPE CANAVERAL TO GODDARD, MESSAGE FORMAT (SHEET 1 OF 2)

NOTES

1. The 5-bit identity (ID) word is each subframe conveys the following information:

   Date from Burroughs–GE High-Speed Buffer and Retransmitter.

   Bit 1: Always a 0.
   Bit 2: A 1 signifies second subframe.
   Bit 3: A 1 signifies first subframe.
   Bit 4: Always a 0.
   Bit 5: Always a 0.

2. In the event that no data is received from the telemetry event transmitting buffer, the high-speed buffer and retransmitters are arranged to transmit 0's in the bit positions occupied by telemetry event data bits 1 through 40 and 43 through 72. Ones are transmitted in positions 41 and 42, resulting in erroneous parity for the telemetry event data message.

3. In the absence of data quantities G, H, J, K, L, M, and N, the complete message frame is transmitted every 650 milliseconds. Telemetry data continues to be transmitted. Zeros with 1's interspersed in certain positions are transmitted in place of the missing data quantities. The following bits appear as 1's in this event:

Subframe	8–Bit Word No.	Quantity	Bit Within Quantity
1	13	G	24
1	16	H	24
1	19	J	24
1	22	K	24
2	3	L	24
2	6	M	24
2	9	N	24
2	10	Checksum	1

FIGURE 2–15. BURROUGHS-GE DATA, CAPE CANAVERAL TO GODDARD, MESSAGE FORMAT (SHEET 2 OF 2)

8-Bit Word Transfers from Data Receiver
First Subframe

Word		
1	1 Telemetry 8	
2	9 Telemetry 16	
3	17 Telemetry 24	
4	25 Telemetry 32	
5	33 Telemetry 40	
6	41 Telemetry 48	
7	49 Telemetry 56	
8	57 Telemetry 64	
9	65 Telemetry 72	
10	1 A 8	
11	9 A 16	
12	17 A 24	
13	25 A 32	
14	33 A 36	1 B 4
15	5 B 12	
16	13 B 20	
17	21 B 28	
18	29 B 36	
19	1 C 8	
20	9 C 16	
21	17 C 24	
22	25 C 32	
23	33 C 36	0 0 0 0
24	0 0 0	1 ID* 5

8-Bit Word Transfers from Data Receiver
Second Subframe

Word		
1	1 D 8	
2	9 D 16	
3	17 D 24	
4	25 D 32	
5	33 D 36	1 E 4
6	5 E 12	
7	13 E 20	
8	21 E 28	
9	29 E 36	
10	1 F 8	
11	9 F 16	
12	17 F 24	
13	25 F 32	
14	33 F 36	1 N 4
15	5 N 12	
16	13 N 20	
17	21 N 28	
18	29 N 36	
19	1 Checksum Σ 8	
20	9 Checksum Σ 16	
21	17 Checksum Σ 24	
22	25 Checksum Σ 32	
23	33 Σ 36	0 0 0 0
24	0 0 0	1 ID* 5

The above constitutes a complete message frame and is transmitted every 400 milliseconds. Each subframe consists of 192 serial bits preceded by a sync signal. The quantities represented by A, B, C, D, E, F, and N are restricted information and are specified in other documents.

***See Note 1 for makeup of ID word.**

FIGURE 2-16. IP 709 DATA, CAPE CANAVERAL TO GODDARD, MESSAGE FORMAT (SHEET 1 OF 2)

See Note 2 for format of bits 1 to 72 of first subframe in absence of telemetry data and Note 3 for format in absence of quantities A, B, C, D, E, F, and N.
See table 2-15 for format of telemetry data.

NOTES

1. The 5-bit identity (ID) word in each subframe conveys the following information

   Data from IP 709 High-Speed Buffer and Retransmitter

   Bit 1: A 0 signifies IP 709 data format.
   A 1 signifies raw radar format.
   Bit 2: A 1 signifies second subframe.
   Bit 3: A 1 signifies first subframe.
   Bit 4 and 5: Indicate source of raw radar data.

2. In the event that no data is received from the telemetry event transmitting buffer, the high-speed buffer and retransmitters are arranged to transmit 0's in the bit positions occupied by telemetry event data bits 1 through 40 and 43 through 72. Ones are transmitters in positions 41 and 42, resulting in erroneous parity for the telemetry event data message.

3. In the absence of data quantities A, B, C, D, E, F, and N, the complete message frame is transmitted every 400 milliseconds. Telemetry data continues to be transmitted. Zeros with 1's interspersed in certain positions are transmitted in place of the missing data quantities. The following bits appear as 1's in this event:

Subframe	8–Bit Word No.	Quantity	Bit within Quantity
1	12	A	24
1	15	B	12
1	18	B	36
1	21	C	24
2	3	D	24
2	6	E	12
2	9	E	36
2	12	F	24
2	15	N	12
2	18	N	36
2	19	Checksum	1

FIGURE 2–16. IP 709 DATA, CAPE CANAVERAL TO GODDARD, MESSAGE FORMAT (SHEET 2 OF 2)

8-Bit Word Transfers from Data Receiver
First Subframe

1	1 Telemetry 8		
2	9 Telemetry 16		
3	17 Telemetry 24		
4	25 Telemetry 32		
5	33 T/M 36	1 P 4	
6	5 P 12		
7	13 P 20		
8	1 Q 8		
9	9 Q 16		
10	17	1 R 7	
11	8 R 15		
12	16 R 17	OT	1 ID* 5
13	37 Telemetry 44		
14	45 Telemetry 52		
15	53 Telemetry 60		
16	61 Telemetry 68		
17	69 T/M 72	1 P 4	
18	5 P 12		
19	13 P 20		
20	1 Q 8		
21	9 Q 16		
22	17	1 R 7	
23	8 R 15		
24	16 R 17	OT	1 ID* 5

8-Bit Word Transfers from Data Receiver
Second Subframe

1	0 0 0 0 0 0 0 0		
2	0 0 0 0 0 0 0 0		
3	0 0 0 0 0 0 0 0		
4	0 0 0 0 0 0 0 0		
5	0 0 0 0	1 P 4	
6	5 P 12		
7	13 P 20		
8	1 Q 8		
9	9 Q 16		
10	17	1 R 7	
11	8 R 15		
12	16 R 17	OT	1 ID* 5
13	0 0 0 0 0 0 0 0		
14	0 0 0 0 0 0 0 0		
15	0 0 0 0 0 0 0 0		
16	0 0 0 0 0 0 0 0		
17	0 0 0 0	1 P 4	
18	5 P 12		
19	13 P 20		
20	1 Q 8		
21	9 Q 16		
22	17	1 R 7	
23	8 R 15		
24	16 R 17	OT	1 ID* 5

The above constitutes a complete message frame and is transmitted every 400 milliseconds. Each subframe consists of 192 serial bits preceded by a sync signal. The quantities represented by P, Q, and R are restricted information and are specified in other documents.

* See Note for makeup of ID word.
See table 2-15 for format of telemetry data.

FIGURE 2–17. RAW RADAR DATA, CAPE CANAVERAL TO GODDARD, MESSAGE FORMAT (SHEET 1 OF 2)

NOTE

The 5-bit identity (ID) word in each subframe conveys the following information:

Data from B-GE High-Speed Buffer and Retransmitter

Bit 1: Always a 0.
Bit 2: A 1 signifies second subframe.
Bit 3: A 1 signifies first subframe.
Bit 4: Always a 0.
Bit 5: Always a 0.

Data from IP 709 High-Speed Buffer and Retransmitter

Bit 1: A 0 signifies IP 709 data format.
A 2 signifies raw radar format.
Bit 2: A 1 signifies second subframe.
Bit 3: A 1 signifies first subframe.
Bits 4 and 5: Indicate source of raw radar data.

FIGURE 2-17. RAW RADAR DATA, CAPE CANAVERAL TO GODDARD, MESSAGE FORMAT (SHEET 2 OF 2)

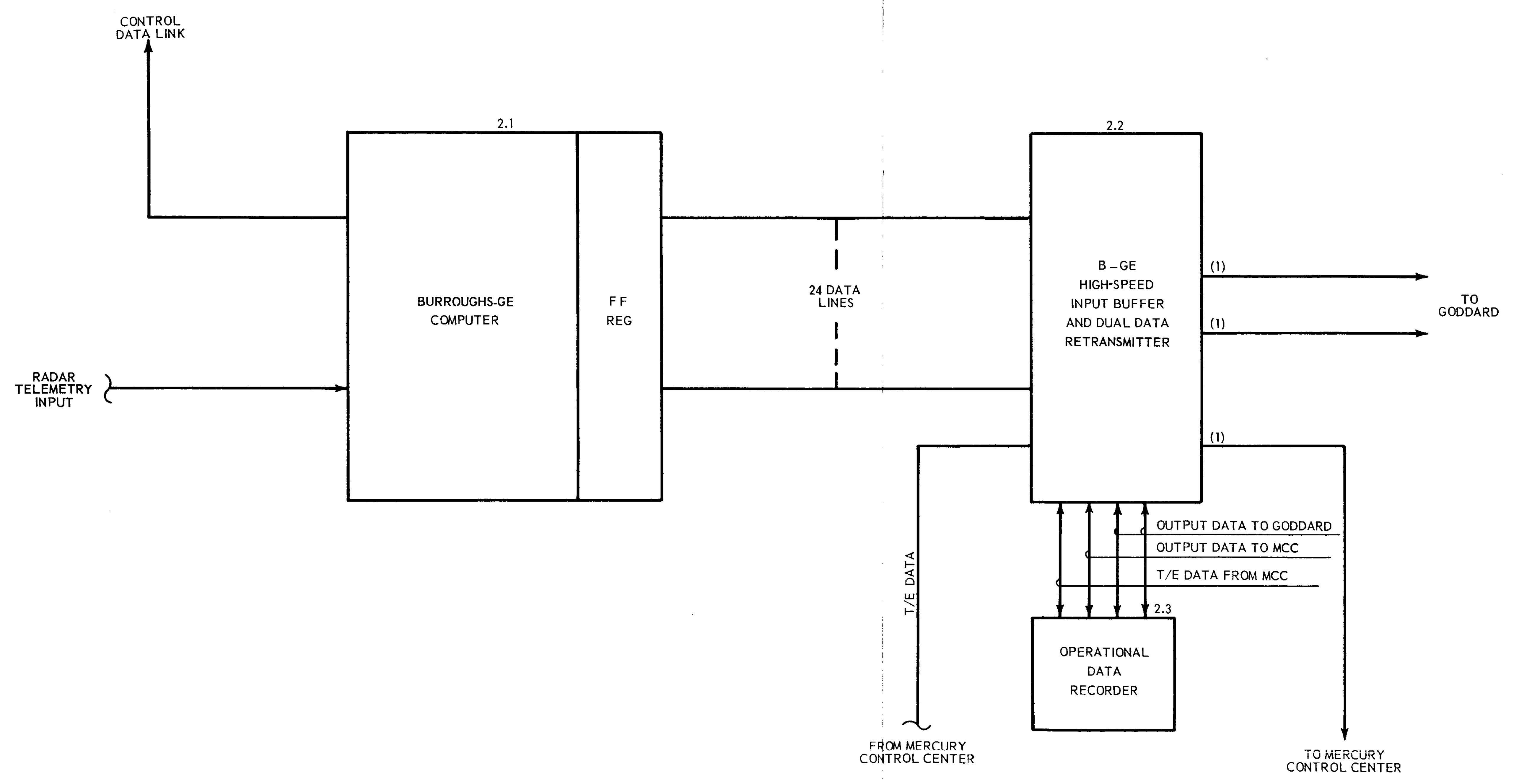


FIGURE 2-18. BURROUGHS-GE COMPLEX, SYSTEM DIAGRAM

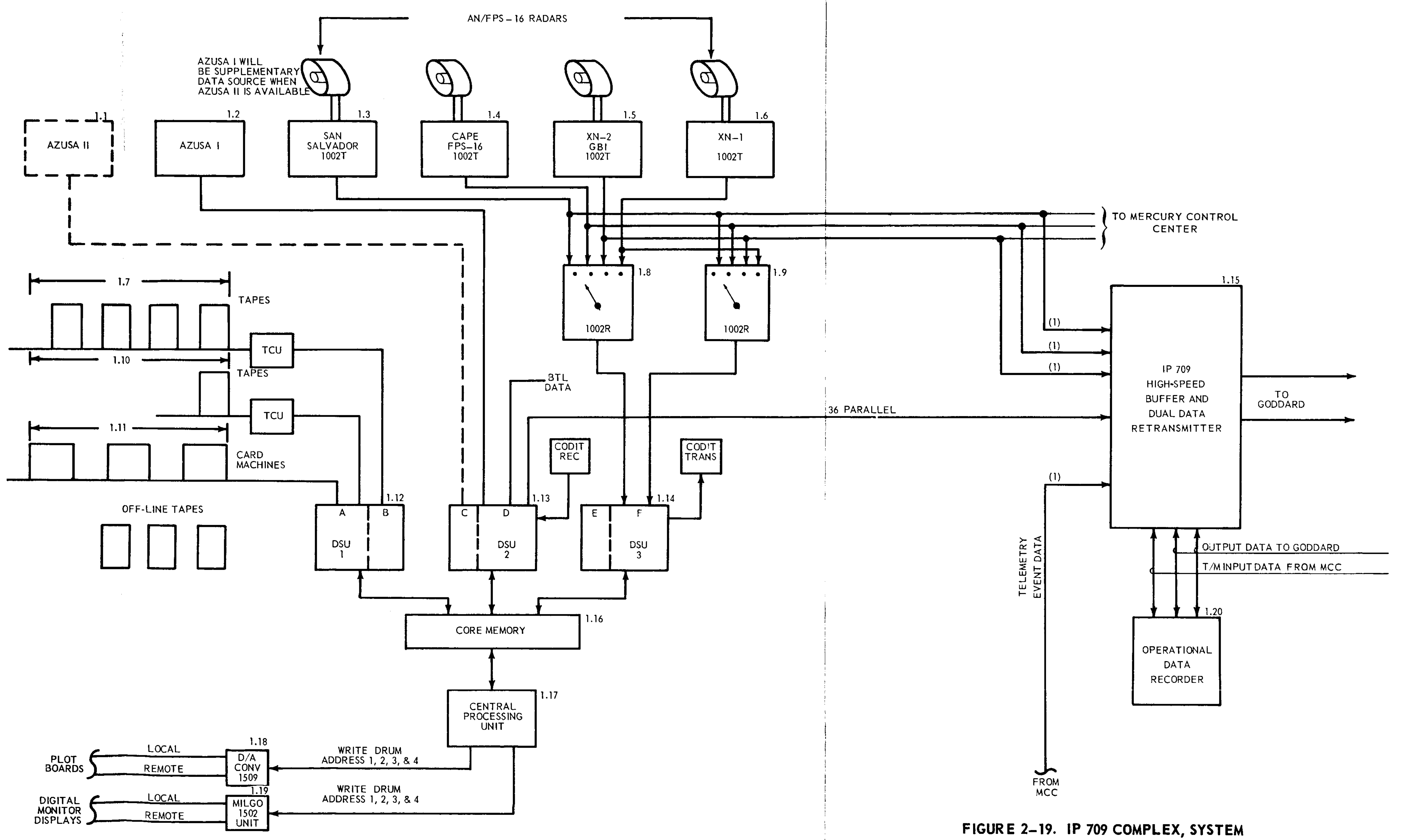


FIGURE 2-19. IP 709 COMPLEX, SYSTEM DIAGRAM

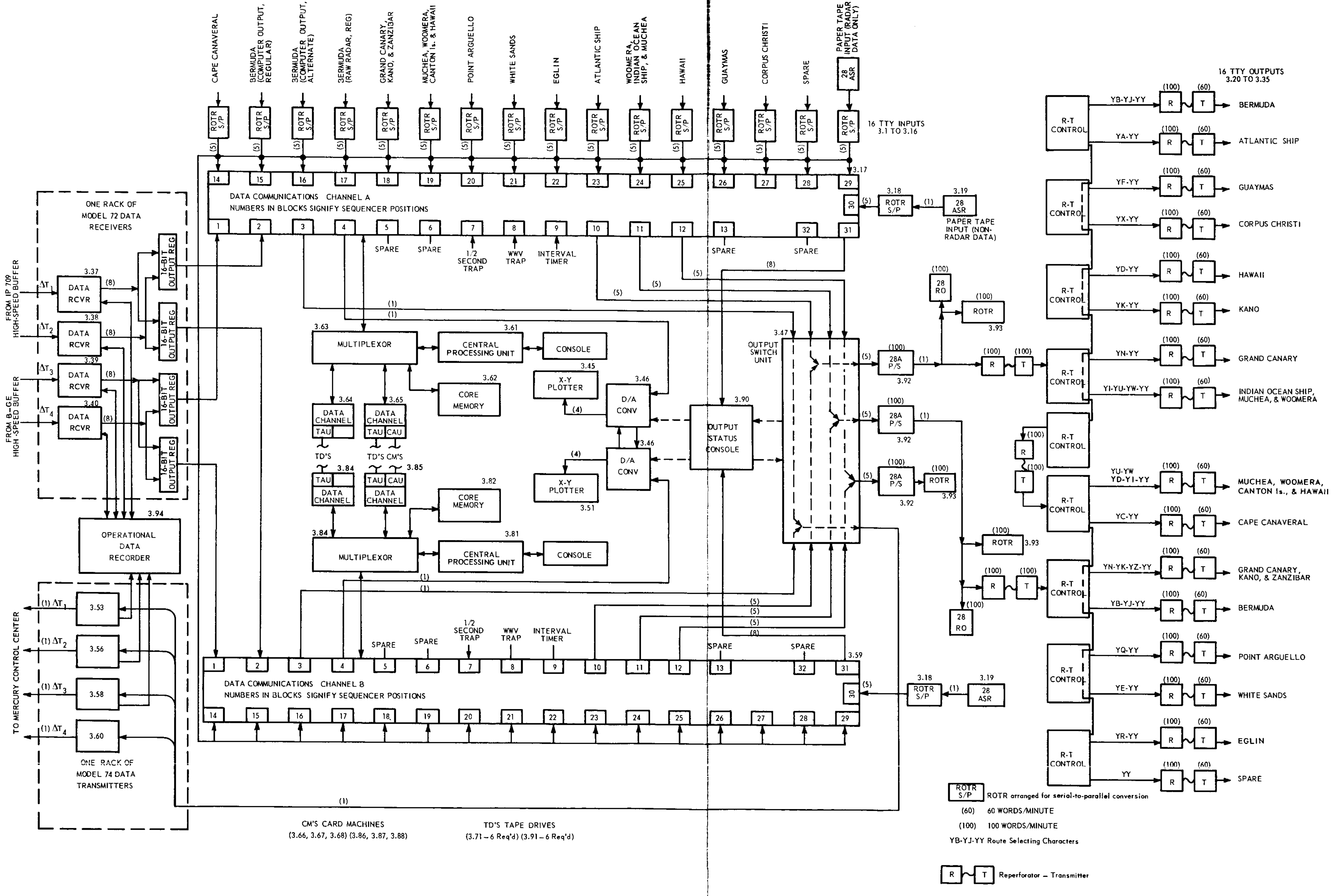


FIGURE 2-20. GODDARD COMPLEX, SYSTEM DIAGRAM

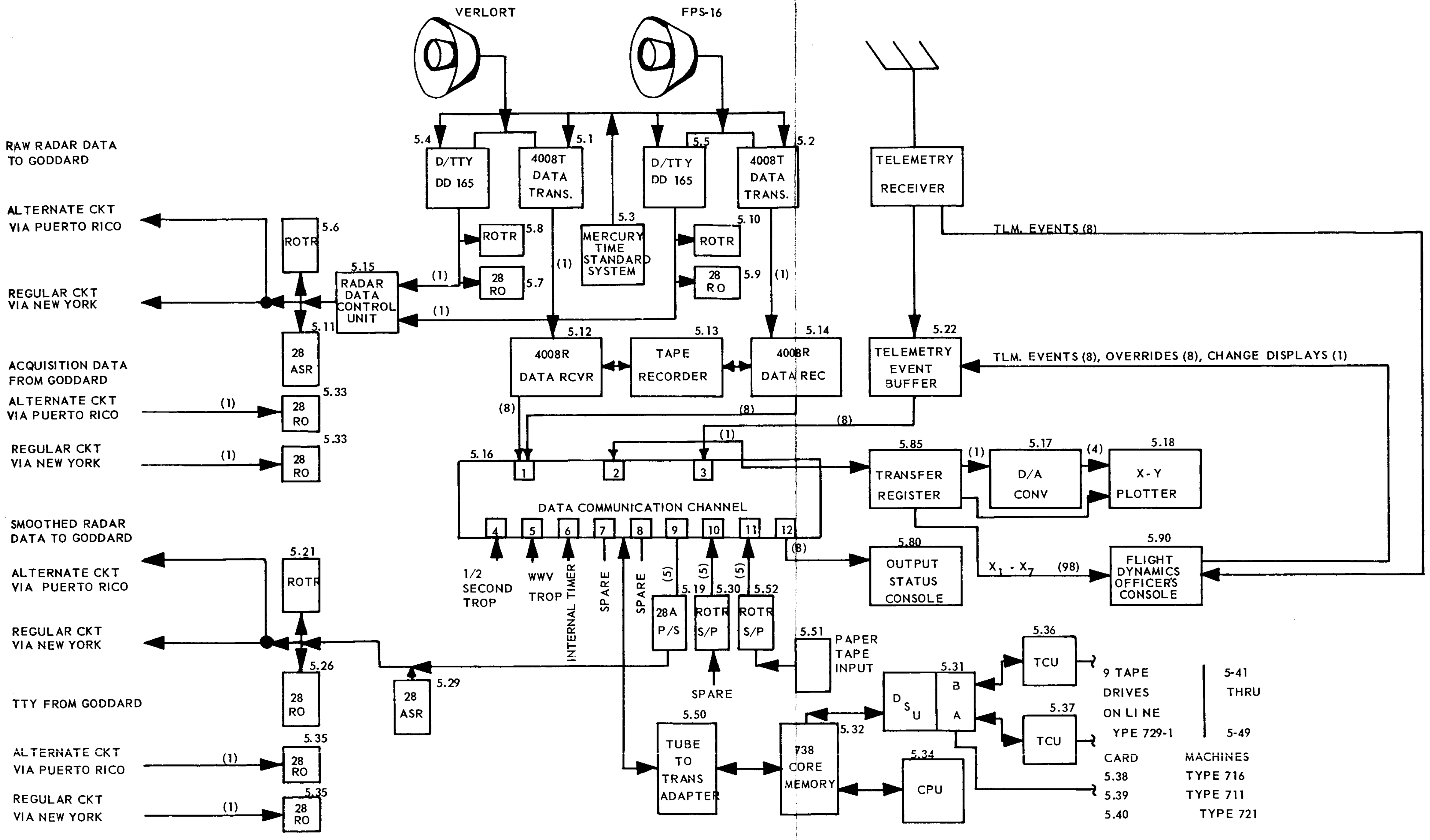


FIGURE 2-21. BERMUDA COMPLEX, SYSTEM DIAGRAM

AN/FPS - 16 Data (← Bit No.)								Word No.	Verlort Data (← Bit No.)							
8	7	6	5	4	3	2	1	↓	8	7	6	5	4	3	2	1
R_{17}	R_{18}	R_{19}	R_{20}	0	0	0	0	1	R_{17}	R_{18}	R_{19}	R_{20}	0	0	0	0
R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	R_{16}	2	R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	R_{16}
R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	3	0	R_2	R_3	R_4	R_5	R_6	R_7	R_8
A_{17}	S	M	S	0	0	0	0	4	0	S	M	S	0	0	0	0
A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	5	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	6	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
E_{17}	S	S	O.T.	0	0	0	0	7	0	S	S	O.T.	0	0	0	0
E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}	E_{16}	8	E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}	E_{16}
E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	9	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8
T_{17}	T_{18}	T_{19}	T_{20}	T_{21}	T_{22}	T_{23}	T_{24}	10	T_{17}	T_{18}	T_{19}	T_{20}	T_{21}	T_{22}	T_{23}	T_{24}
T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	11	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}
T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	12	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8

Least significant bit of each quantity is received first. Words 1 to 12 are transferred from each receiver into real-time channel in sequence. The data receivers are synchronized so that the FPS-16 message and the Verlort message are in synchronism.

Range, azimuth, and elevation are digital values. The units of each quantity are such that the quantization represented by 1 bit is:

	FPS-16	Verlort
Range	1.000064 yd	9.767803 yd
Azimuth	0.048828125 mil	0.09765625 mil
Elevation	0.048828125 mil	0.09765625 mil

Time T_1 to T_{24} is BCD as follows:

T_{24} = 0.1 sec.	T_{18} = 4.0 sec.	T_{12} = 2.0 min	T_6 = 1.0 hr
T_{23} = 0.2 sec.	T_{17} = 8.0 sec.	T_{11} = 4.0 min	T_5 = 2.0 hr
T_{22} - 0.4 sec.	T_{16} = 10.0 sec.	T_{10} = 8.0 min	T_4 = 4.0 hr
T_{21} = 0.8 sec.	T_{15} = 20.0 sec.	T_9 = 10.0 min	T_3 = 8.0 hr
T_{20} = 1.0 sec.	T_{14} = 40.0 sec.	T_8 = 20.0 min	T_2 = 10.0 hr
T_{19} = 2.0 sec.	T_{13} = 1.0 min	T_7 = 40.0 min	T_1 = 20.0 hr

Bit 5 in word 7 (OT) is the on-track bit and is a 1 when the output data is valid track information.

Bit 6 in word 4 (M) is a 1-second marker bit and is utilized by the data receiver.

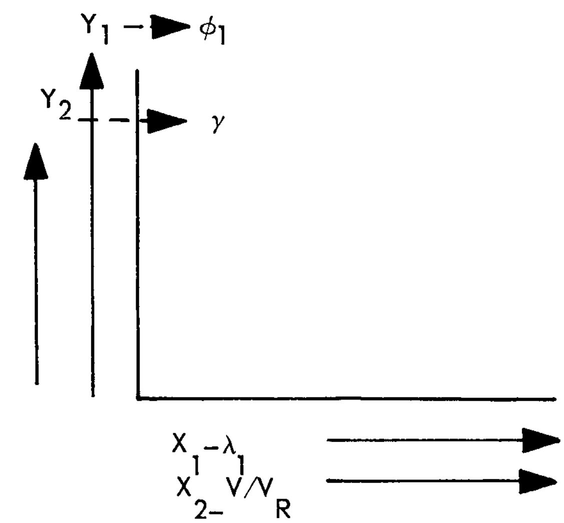
Bit 5 and 7 of word 4 and bits 6 and 7 of word 7 (S) are synchonization bits and are utilized by the data receiver.

FIGURE 2-22. RADAR TO IBM 709, BERMUDA, MESSAGE FORMAT

Before retrofire

ϕ_1 and λ_1 -- Latitude and longitude of impact point for immediate retrofire.

γ Flight path angle
V/V_R = Velocity ratio



(See table 2-22 for summary of display quantities and scaling.)

After Retrofire

ϕ_{IP} and λ_{IP} - Latitude and longitude of impact point.

ϕ_{PP} and λ_{PP} -- Latitude and longitude of capsule present position.

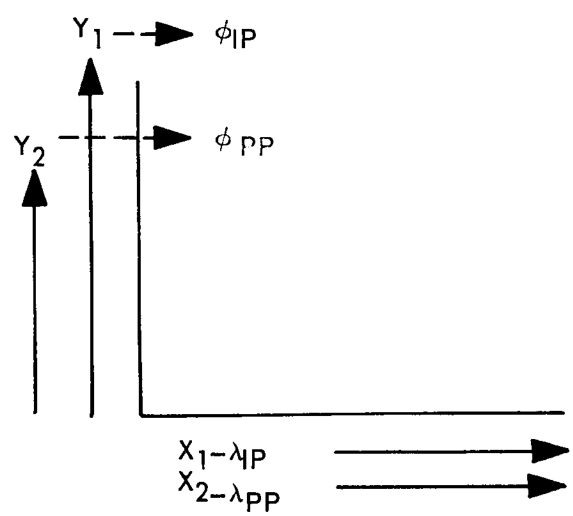


FIGURE 2-23. PLOT BOARD I (BERMUDA), REPRESENTATION OF DISPLAYS

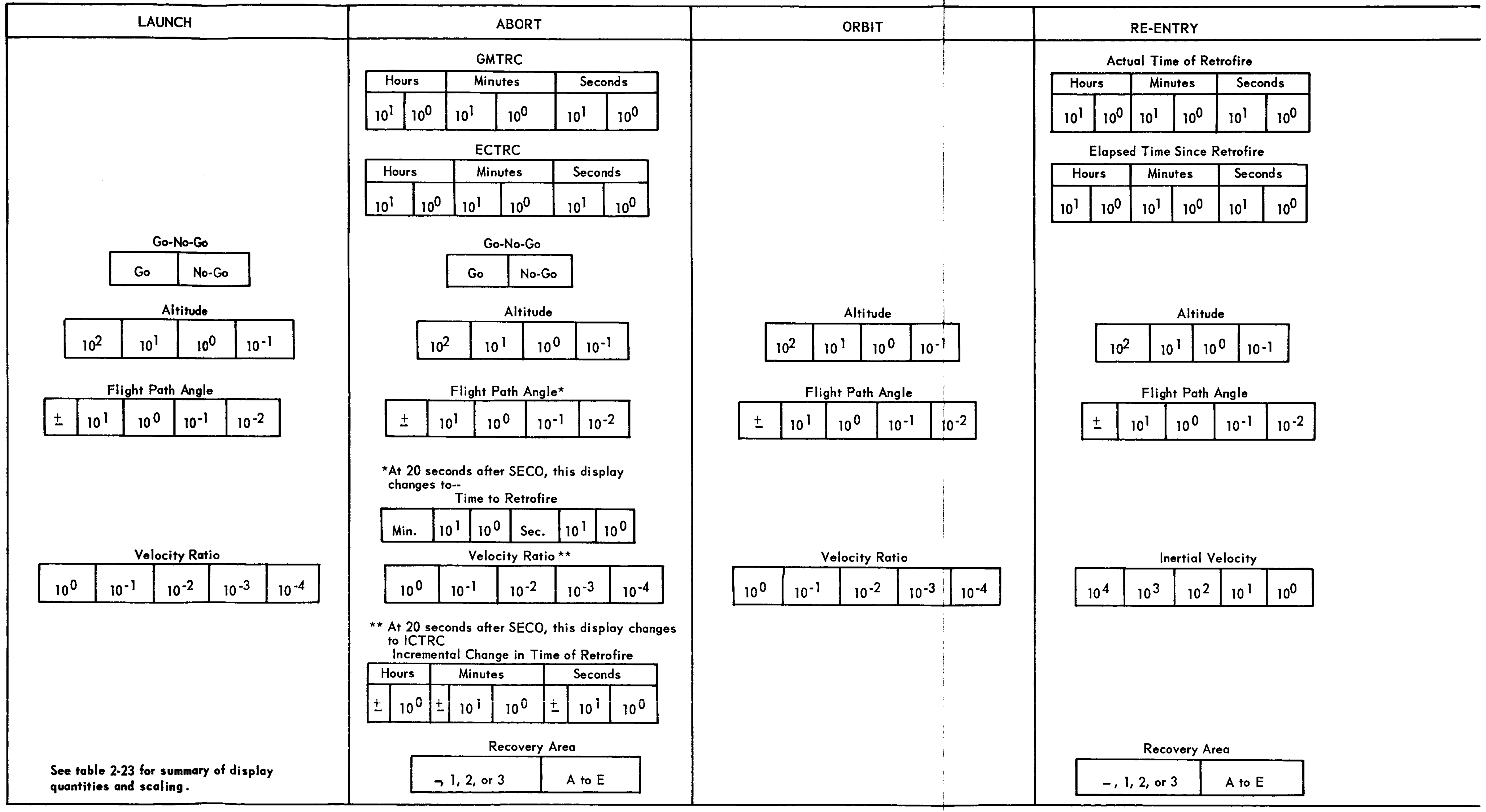


FIGURE 2–24. FLIGHT DYNAMICS OFFICER'S CONSOLE (BERMUDA), REPRESENTATION OF DISPLAYS

TABLE 2-1. PLOT BOARD I (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed				Digital Inputs to D/A Converters					
				Zero Display	Full Scale	Units per In.	Notes	Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch Phase													
	X_{1A}	V/V_R	–	0.0	1.5	0.05	1,2	IBM 7090 or B-GE	10	$\frac{1.5}{1023}$	$2 \cdot \frac{1.5}{1023}$	$2^9 \cdot \frac{1.5}{1023}$	1,2
	Y_{1A}	Y	deg	0	60	2	1,2		10	$\frac{60}{1023}$	$2 \cdot \frac{60}{1023}$	$2^9 \cdot \frac{60}{1023}$	1,2
	X_{1B}	V/V_R	–	0.90	1.05	0.005	1,2		10*	$\frac{0.15}{1023}$	etc.	etc.	1 to 4
	Y_{1B}	γ	deg	-1.0	+2.0	0.1	1,2	IBM 7090 or B-GE	10*	$\frac{3}{1023}$			1 to 4
	X_2	Spare					1	7090	10				1
	Y_2	Spare					1	7090	10		etc.	etc.	1
	X_3	Go Recommendation	Go	0	Go	1		IBM 7090 or B-GE	1	1	–	–	6
		No-Go Recommendation	No-Go	0	No-Go	1		IBM 7090 or B-GE	1	1	–	–	6
Abort Phase													
	X_1	V	ft/sec.	0	30,000	1,000	1	IBM 7090	10*	$\frac{30,000}{1023}$	etc.	etc.	1,4,5
	Y_1	$r - \bar{R}$	naut.mi.	0	200	$\frac{20}{3}$	1		10*	$\frac{200}{1023}$			1,4,5
	X_2	Spare	–				1		10*				1, 4
	Y_2	Spare	–				1		10*		etc.	etc.	1, 4
	X_3	Go Recommendation	Go	0	Go	1			1	1	–	–	
		No-Go Recommendation	No-Go	0	No-Go	1		IBM 7090	1	1	–	–	

TABLE 2-1. PLOT BOARD I (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES (cont'd)

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	How Displayed: Full Scale	How Displayed: Units per In.	How Displayed: Notes	Digital Inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Orbit and Re-entry Phases													
	X_1	V	ft/sec.	0	30,000	1,000	1	IBM 7090	10*	$\frac{30,000}{1023}$	$2 \cdot \frac{30,000}{1023}$	$2^9 \cdot \frac{30,000}{1023}$	1,4,5
	Y_1	$r - \tilde{R}$	naut.mi.	0	200	$\frac{20}{3}$	1	IBM 7090	10*	$\frac{200}{1023}$	$2 \cdot \frac{200}{1023}$	$2^9 \cdot \frac{200}{1023}$	1,4,5
	X_2	Spare	–				1	IBM 7090	10*				1,4
	Y_2	Spare	–				1	IBM 7090	10*				1,4

*See Note 4

NOTES

1. Time marks are supplied by IBM 7090 with data associated with 10, 20, etc., and 61, 121, etc., seconds after liftoff during the launch and abort phases; 10, 20, etc., and 61, 121, etc., minutes after liftoff during the orbit phase; and every minute after liftoff during the re-entry phase.
2. The first plot (X_{1A}, Y_{1A}) is discontinued when $V/V_R \geq 0.9$ by the computer and is replaced by the second plot (X_{1B}, Y_{1B}) using the same bits and D/A converters.
3. The computers zero-offset this data as follows:
   $X_1 = V/V_R - 0.9, Y_1 = \delta + 1$ degrees
4. The bits and/or D/A's for this display are time-shared with bits already listed and therefore should not be counted as additional bits.
5. Must be switched, at switch unit, to IBM 7090 data during abort, orbit, and re-entry.
6. The GO, NO GO indicators are activated by the B-GE computer or by the IBM 7090 computer, so that the source of the go, no-go recommendation is the same as that for Plot Boards I and II.

The go, no-go bit from the B-GE computer is conditioned by the SECO bit from B-GE in accordance with the following:

SECO Bit	Go, No-Go Bit	SECO Light	Go Light Green	No-Go Light Red
0	0	Off	Off	Off
0	1	Off	Off	Off
1	0	On	Off	On
1	1	On	On	Off

The two bits indicating go or no-go from the IBM 7090 computer provide go, no-go indication as defined below:

Bits	Go Light Green	No-Go Light Red
00	Off	Off
01	Off	On
10	On	Off
11	On	On

TABLE 2-2. PLOT BOARD II (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	Full Scale	Units per In.	Notes	Digital Inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch Phase													
	X_1	d	naut.mi.	0	600	20	1	IBM 7090 or B-GE	10	$\frac{600}{1023}$	$2 \cdot \frac{600}{1023}$	$2^9 \cdot \frac{600}{1023}$	1
	Y_1	h	naut.mi.	0	150	5		IBM 7090 or B-GE	10	$\frac{150}{1023}$	etc.	etc.	
	X_2	d	naut.mi.	0	600	20	1	(Same D/A that feeds X_1)					1
	Y_2	$y - y_{nom}$	naut.mi.	- 130	+20	5		IBM 7090 or B-GE	10	$\frac{150}{1023}$	etc.	etc.	2
	X_3	Data Source	(See Note 5)			–	5	IBM 7090	3	(See Note 5)			5
		Data Source		0	B-GE Direct	1		DQM Console	1	B-GE Direct	–	–	
Abort Phase													
	X_1	d	naut.mi.	0	600	20	1	IBM 7090	10*	$\frac{600}{1023}$	$2 \cdot \frac{600}{1023}$	$2^9 \cdot \frac{600}{1023}$	1
	Y_1	h	naut.mi.	0	150	5		IBM 7090	10*	$\frac{150}{1023}$	$2 \cdot \frac{150}{1023}$	$2^9 \cdot \frac{150}{1023}$	
	X_2	d	naut.mi.	0	600	20	1	(Same D/A that feeds X_1)					1
	Y_2	–	–										
Orbit Phase													
	X_1	t_e	hours	0	5	$\frac{1}{6}$	1	IBM 7090	10*	$\frac{5}{1023}$	$2 \cdot \frac{5}{1023}$	$2^9 \cdot \frac{5}{1023}$	1,3,4
	Y_1	h	naut.mi.	0	600	20		IBM 7090	10*	$\frac{600}{1023}$	$2 \cdot \frac{600}{1023}$	$2^9 \cdot \frac{600}{1023}$	3,4
	X_2	t_e	hours	0	5	$\frac{1}{6}$	1	(Same D/A that feeds X_1)					1,4

TABLE 2.2. PLOT BOARD II (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES (cont'd)

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	Full Scale	Units per In.	Notes	Digital Inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
	Y_2	$a - \bar{R}$	naut.mi	−400	+200	20		IBM 7090	10*	$\frac{600}{1023}$	$2 \cdot \frac{600}{1023}$	$2^9 \cdot \frac{600}{1023}$	2,3,4
	X_4	orbit phase	–	0	Orbit	1		DQM	1	1	–	–	
Re–entry Phase													
	Y_1	t_e	hours	0	5	$\frac{1}{6}$	1	IBM 7090	10*	$\frac{5}{1023}$	$2 \cdot \frac{5}{1023}$	$2^9 \cdot \frac{5}{1023}$	1,3,4
	Y_1	h	naut.mi.	0	600	20		IBM 7090	10*	$\frac{600}{1023}$	$2 \cdot \frac{600}{1023}$	$2^9 \cdot \frac{600}{1023}$	3,4
	X_2	t_e	hours	0	5	$\frac{1}{6}$	1	(Same D/A that feeds X_1)					1,4
	Y_2	–	–										

*See Note 3

NOTES

1. Time marks are supplied by the IBM 7090 with data associated with 10, 20, etc., and 61, 121, etc., seconds after liftoff during the launch and abort phases; 10, 20, etc., and 61, 121, etc., minutes after liftoff during the orbit phase; and every minute after liftoff during the re-entry phase.
2. The computers zero-offset this data.
3. The bits and/or D/A's for this display are time-shared with bits already listed and therefore should not be counted as additional bits.
4. Must be switched, at switch unit, to IBM 7090 data during abort, orbit, and re-entry.
5. Data source indicated by bits 41, 42, and 83 of message format, Goddard to MCC (table 2 – 13) as follows:

010	Raw radar	110	IP 709, Azusa input
100	B-GE data	111	IP 709, FPS-16 input

TABLE 2-3. PLOT BOARD III (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	Full Scale	Units per In.	Notes	Digital Inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch phase													
	X_{1A}	t_e	secs.	0	300	10	1,3	B-GE	10	$\frac{300}{1023}$	$2 \cdot \frac{300}{1023}$	$2^9 \cdot \frac{300}{1023}$	1
	Y_{1A}	V	ft/sec.	0	30,000	1,000	3	B-GE	10	$\frac{30,000}{1023}$	etc.	etc.	
	X_{1B}	t_{go}	secs.	+140	-10	5	1,3	B-GE	10	$\frac{150}{1023}$	etc.	etc.	1,2
	Y_{1B}	V_y	ft/sec.	-750	+2,250	100	3	B-GE	10	$\frac{3,000}{1023}$	etc.	etc.	2
	X_{2A}	t_e	secs.	0	300	10	1,3	(Same D/A that feeds X_{1A})					1
	Y_{2A}	a_T	g's	-7.5	+7.5	0.5	3	TLM Receiver	–	–	–	–	Analog Input
	X_{2B}	t_{go}	secs.	+140	-10	5	1,3	(Same D/A that feeds X_{1B})					1
	Y_{2B}	h_{ins}	naut. mi.	+85	+115	1	3	B-GE	10	$\frac{30}{1023}$	etc.	etc.	2
Orbit phase													
	X_1	t_e	hours	0	5	$\frac{1}{6}$	1	7090	10	$\frac{5}{1023}$	etc.	etc.	1,4
	Y_1	λ_p	deg.	-180	+540	24		7090	10	$\frac{720}{1023}$	etc.	etc.	2,4
	X_2	t_e	hours	0	5	$\frac{1}{6}$	1	(Same D/A that feeds X_1)					1
	Y_2	ϵ	–	-0.144	+0.144	$\frac{0.288}{30}$		7090	10	$\frac{0.288}{1023}$	etc.	etc.	4

NOTES

1. Time marks are supplied by the IBM 7090 with data associated with 10, 20, etc., and 61, 121, etc., seconds after liftoff during the launch and abort phases; 10, 20, etc., and 61, 121, etc., minutes after liftoff during the orbit phase; and every minute after liftoff during the re-entry phase.
2. The computers zero-offset this data.
3. This plotter switches from the first two plots (X_{1A}, Y_{1A}, and X_{2A}, Y_{2A}) to the other two plots (X_{1B}, Y_{1B} and X_{2B}, Y_{2B}) when the elapsed time from liftoff equals 175 seconds. The relay is part of the plotter.
4. Must be switched, at switch unit, to IBM 7090 data during abort, orbit, and re-entry.

TABLE 2-4. PLOT BOARD IV (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed				Digital Inputs to D/A Converters					
				Zero Display	Full Scale	Units per In.	Notes	Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch phase													
	X_{1A}	λ_{IP}	deg	−82	+8	3	1,4	7090	10	$\frac{90}{1023}$	$2 \cdot \frac{90}{1023}$	$2^9 \cdot \frac{90}{1023}$	1,2,4
	Y_{1A}	ϕ_{IP}	deg	+12	+36	0.8	4	7090	10	$\frac{24}{1023}$	etc.	etc.	2,4
	X_{1B}	$\lambda_{30\ sec.}$	deg	−82	+8	3	1,4	7090	10*	$\frac{90}{1023}$	etc.	etc.	1,2,3,4
	Y_{1B}	$\phi_{30\ sec.}$	deg	+12	+36	0.8	4	7090	10*	$\frac{24}{1023}$	etc.	etc.	2,3,4
	X_2	$\lambda_{max\ delay}$	deg	−82	+8	3	1,4	7090	10	$\frac{90}{1023}$	etc.	etc.	1,2,4
	Y_2	$\phi_{max\ delay}$	deg	+12	+36	0.8	4	7090	10	$\frac{24}{1023}$	etc.	etc.	2,4
Abort phase													
	X_1	λ_{IP}	deg	−82	+8	3	1	7090	10*	$\frac{90}{1023}$	etc.	etc.	1,2,3
	Y_1	ϕ_{IP}	deg	+12	+36	0.8		7090	10*	$\frac{24}{1023}$	etc.	etc.	2,3
	X_2	λ_{PP}	deg	−82	+8	3	1	7090	10*	$\frac{90}{1023}$	etc.	etc.	1,2,3
	Y_2	ϕ_{PP}	deg	+12	+36	0.8		7090	10*	$\frac{24}{1023}$	etc.	etc.	2,3

TABLE 2-4. PLOT BOARD IV (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES (cont'd)

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	How Displayed: Full Scale	How Displayed: Units per In.	How Displayed: Notes	Digital Inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Orbit phase													
	X_1	$\lambda_{30\ sec.}$	deg	−135	−45	3	1	7090	10*	$\frac{90}{1023}$	$2 \cdot \frac{90}{1023}$	$2^9 \cdot \frac{90}{1023}$	1,2,3
	Y_1	$\phi_{30\ sec.}$	deg	+12	+36	0.8		7090	10*	$\frac{24}{1023}$	etc.	etc.	2,3
	X_2	λ_{PP}	deg	−135	−45	3	1	7090	10*	$\frac{90}{1023}$	etc.	etc.	1,2,3
	Y_2	ϕ_{PP}	deg	+12	+36	0.8		7090	10*	$\frac{24}{1023}$	etc.	etc.	2,3
Re-entry phase													
	X_1	λ_{IP}	deg	−82	+8	3	1	7090	10*	$\frac{90}{1023}$	etc.	etc.	1,2,3
	Y_1	ϕ_{IP}	deg	+12	+36	0.8		7090	10*	$\frac{24}{1023}$	etc.	etc.	2,3
	X_2	λ_{PP}	deg	−82	+8	3	1	7090	10*	$\frac{90}{1023}$	etc.	etc.	1,2,3
	Y_2	ϕ_{PP}	deg	+12	+36	0.8		7090	10*	$\frac{24}{1023}$	etc.	etc.	2,3

*See Note 3

NOTES

1. Time marks are supplied by the IBM 7090 with data associated with 10, 20, etc., and 61, 121, etc., seconds after liftoff during the launch and abort phases; 10, 20, etc., and 61, 121, etc., minutes after liftoff during the orbit phase; and every minute after liftoff during the re-entry phase.
2. The computers zero-offset this data.
3. The bits and/or D/A's for this display are time-shared with bits already listed and therefore should not be counted as additional bits.
4. One plot (X_{1A}, Y_{1A}) is furnished, by the computer, until escape tower separation has occurred. Thereafter two plots (X_{1B}, Y_{1B} and X_2, Y_2) are computed and displayed.

TABLE 2-5. FLIGHT DYNAMICS OFFICER'S CONSOLE (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	Full Scale	Units per In.	Notes	Digital Inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch, Abort, Orbit, Re-entry phases													
	X_1	Go Recommendation	Go	0	Go	1		IBM 7090 or B-GE	1	1	–	–	4
		No-Go Recomm.	No Go	0	No-Go	1		IBM 7090 or B-GE	1	1	–	–	4
	X_2	$r - \bar{R}$	naut. mi.	0.0	0.9	0.1		7090	4	0.1	0.2	0.8	
		$r - \bar{R}$	naut. mi.	0	9	1		7090	4	1	2	8	
		$r - \bar{R}$	naut. mi.	0	90	10		7090	4	10	20	80	
		$r - \bar{R}$	naut. mi.	0	900	100		7090	4	100	200	800	
	X_{3A}	γ	deg	0.00	0.09	0.01	2	7090	4	0.01	0.02	0.08	2
		γ	deg	0.0	0.9	0.1	2	7090	4	0.1	0.2	0.8	2
		γ	deg	0	9	1	2	7090	4	1	2	8	2
		γ	deg	0	90	10	2	7090	4	10	20	80	2
		γ	±	+	–	1	2	7090	1	1	–	–	2
	X_{3B}	h_a	naut. mi.	0.0	0.9	0.1	2	7090	4*	0.1	0.2	0.8	1,2
		h_a	naut. mi.	0	9	1	2	7090	4*	1	2	8	1,2
		h_a	naut. mi.	0	90	10	2	7090	4*	10	20	80	1,2
		h_a	naut. mi.	0	900	100	2	7090	4*	100	200	800	1,2
		(Not used for	X_{3B})					7090	1*	(Not used	for X_{3B})		1,2

TABLE 2-5. FLIGHT DYNAMICS OFFICER'S CONSOLE (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES (cont'd)

Where Displayed & Phase	Plot	Quantity	Units	How Displayed				Digital Inputs to D/A Converters					
				Zero Display	Full Scale	Units per In.	Notes	Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
	X_4	Inclination Angle	deg	0.0	0.9	0.1		7090	4	0.1	0.2	0.8	
		same	deg	0	9	1		7090	4	1	2	8	
		same	deg	0	90	10		7090	4	10	20	80	
	X_5	Orbit Capability	number	0	9	1		7090	4	1	2	8	
		same	number	0	30	10		7090	2	1	–	2	
	X_{6A}	V/V_R	–	0.0000	0.0009	0.0001	3	7090	4	0.0001	0.0002	0.0008	3
		V/V_R	–	0.000	0.009	0.001	3	7090	4	0.001	0.002	0.008	3
		V/V_R	–	0.00	0.09	0.01	3	7090	4	0.01	0.02	0.08	3
		V/V_R	–	0.0	0.9	0.1	3	7090	4	0.1	0.2	0.8	3
		V/V_R	–	0	3	1	3	7090	2	1	–	2	3
	X_{6B}	V	ft/sec.	0	9	1	3	7090	4*	1	2	8	1,3
		V	ft/sec.	0	90	10	3	7090	4*	10	20	80	1,3
		V	ft/sec.	0	900	100	3	7090	4*	100	200	800	1,3
		V	ft/sec.	0	9000	1000	3	7090	4*	1000	2000	8000	1,3
		V	ft/sec.	0	30,000	10,000	3	7090	2*	10,000	–	20,000	1,3

*See Note 1

TABLE 2-5. FLIGHT DYNAMICS OFFICER'S CONSOLE (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES (cont'd)

NOTES

1. The bits and/or D/A's for this display are time-shared with bits already listed and therefore should not be counted as additional bits.

2. Display X_{3A} is replaced by X_{3B} during orbit phase. During re-entry, X_{3A} is again displayed.

3. Display X_{6A} is replaced by X_{6B} at beginning of abort, orbit, or re-entry phase.

4. The GO, NO GO indicators are activated by the B-GE computer or by the IBM 7090 computer, so that the source of the go, no go recommendation is the same as that for Plot Boards I and II.

   The go, no-go bit from the B-GE computer is conditioned by the SECO bit from B-GE in accordance with the following:

SECO Bit	Go, No-Go Bit	SECO Light	Go Light Green	No-Go Light Red
0	0	Off	Off	Off
0	1	Off	Off	Off
1	0	On	Off	On
1	1	On	On	Off

   The two bits indicating go or no-go from the IBM 7090 computer provide go, no-go indication as defined below:

Bits	Go Light Green	No-Go Light Red
00	Off	Off
01	Off	On
10	On	Off
11	On	On

TABLE 2-6. RETROFIRE CONTROLLER'S CONSOLE (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed				Digital Inputs to D/A Converters					
				Zero Display	Full Scale	Units per In.	Notes	Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch, Abort, Orbit, Re-entry phases													
	X_1	GMTRC for Abort	sec., min hrs	0	23 hr, 59 min, 59 s.	1 sec.	4	7090	20				4
	X_{2A}	ΔT	sec., min hrs	0	23 hr, 59 min, 59 s.	1 sec.	2,4	7090	20				2,4
	X_{2B}	ECTRC for Abort	sec., min hrs	0	23 hr, 59 min, 59 s.	1 sec.	2,4	7090	20*				1,2,4,6
	X_3	GMTRC end pres. O.	sec., min hrs	0	23 hr, 59 min, 59 s.	1 sec.	4	7090	20				4
	X_4	ECTRC end pres. O.	sec., min hrs	0	23 hr, 59 min, 59 s.	1 sec.	4	7090	20				4,6
	X_5	GMTRC end 3 Orb.	sec., min hrs	0	23 hr, 59 min, 59 s.	1 sec.	4	7090	20				4
	X_6	ECTRC end 3 Orb.	sec., min hrs	0	23 hr, 59 min, 59 s.	1 sec.	4	7090	20				4,6
	X_{7A}	GMTRS now	sec., min hrs	0	23 hr, 59 min, 59 s.	1 sec.	3,4	7090	20				3,4
	X_{7B}	EGT since Retrofire	sec., min hrs	0	23 hr, 59 min, 59 s.	1 sec.	3,4	7090	20*				1,3,4
	X_8	ICTRC	sec.	0	59	1 sec.	4	7090	7				4
		Retard setting	Retard secs.	Green: Advance	Red: Retard	1		7090	1	1	–	–	
		ICTRC	min.	0	59	1 min	4	7090	7				4
		Retard setting	Retard mins.	Advance	Retard	1		7090	1	1	–	–	
		ICTRC	hours	0	23	1 hr	4	7090	6				4
		Retard setting	Retard hours	Advance	Retard	1		7090	1	1	–	–	
	X_9	Recovery area	number	A	H	1	5	7090	3	1	2	4	5
		Recovery area	number	–	3	1	5	7090	2	1	2	–	5

*See note 1

TABLE 2-6. RETROFIRE CONTROLLER'S CONSOLE (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES (cont'd)

NOTES

1. The bits and/or D/A's for this display are time-shared with bits already listed and therefore should not be counted as additional bits.
2. Display X_{2A} is replaced by X_{2B} if abort is commanded or when launch phase ends.
3. Display X_{7A} is replaced by X_{7B} when retrofire occurs.
4. Same digital format as X_1 of wall digital display.
5. Recovery area is indicated by a 5-bit quantity designating a 1- or 2-letter identification, as follows:

Bits (1,2)	Letter	Bits (3,4,5)	Letter	Bits (3,4,5)	Letter
00	- -	000	A	100	E
01	1	001	B	101	F
10	2	010	C	110	G
11	3	011	D	111	H

6. Three values of ECTRC, asgiven for X_2, X_4, and X_6 on retrofire controller's console, are available to capsule communicator's console for selection of one value for display.

TABLE 2-7. RECOVERY STATUS MONITOR CONSOLE (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	Full Scale	Units per In.	Notes	Digital Inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Abort, Orbit, and Re-entry Phases													
	X_1	GMTLC	min	0	9	1		7090	4	1	2	8	
			min	0	50	10			3	10	20	40	
			hours	0	9	1			4	1	2	8	
		GMTLC	hours	0	20	10			2	10	–	20	
	X_2	$\lambda_{landing}$	min	0	9	1			4	1	2	8	
			min	0	50	10			3	10	20	40	
			deg	0	9	1			4	1	2	8	
			deg	0	90	10			4	10	20	80	
			deg	0	100	100			1	100	–	–	
		$\lambda_{landing}$	+ East – West	+	–	1			1	1	–	–	
	X_3	$\phi_{landing}$	min	0	9	1			4	1	2	8	
			min	0	50	10			3	10	20	40	
			deg	0	9	1			4	1	2	8	
			deg	0	90	10			4	10	20	80	
		$\lambda_{landing}$	+ North – South	+	–	1		7090	1	1	–	–	

TABLE 2-8. LAUNCH VEHICLE TELEMETRY MONITOR CONSOLE (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed				Digital Inputs to D/A Converters					
				Zero Display	Full Scale	Units per In.	Notes	Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
	X_1	BECO	–	No	Yes	1		B-GE	1	1	–	–	
	X_2	SECO	–	No	Yes	1		B-GE	1	1	–	–	

TABLE 2-9. CAPSULE COMMUNICATOR'S CONSOLE (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed				Digital Inputs to D/A Converters					
				Zero Display	Full Scale	Units per In.	Notes	Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch, Abort, Orbit, and Re-entry Phases													
	X_1	Desired Retro-	Seconds, minutes,	0	23 hrs. 59 min	1 sec.	1 to 4	7090	20				
		setting (ECTRC)	hours		59 sec.								

NOTES

1. The bits and/or D/A's for this display are time-shared with bits already listed and therefore should not be counted as additional bits.
2. Display X_{2A} is replaced by X_{2B} if abort is commanded or when launch phase ends.
3. Same digital format as X_1 of wall digital display.
4. Three values of ECTRC, as given for X_2, X_4, and X_6 on retrofire controller's console, are available to capsule communicator's console for selection of one value for display.

TABLE 2-10. WALL DIGITAL DISPLAY (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed				Digital inputs to D/A Converters					
				Zero Display	Full Scale	Units per In.	Notes	Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch, Abort, and Orbit Phases													
	X_1	GTRS	sec.	0	9	1		7090	4	1	2	8	
			sec.	0	50	10			3	10	20	40	
			min	0	9	1			4	1	2	8	
			min	0	50	10			3	10	20	40	
			hours	0	9	1			4	1	2	8	
		GTRS	hours	0	20	10			2	10	–	20	
	X_2	ORBIT IN PROGRESS	–	0	9	1			4	1	2	8	
		same	–	0	10	10		7090	1	1	–	–	
Re-entry phase													
	X_1	Time remain-ing to land'g	sec, min, & hours				2	7090	20*				1,2
	X_2	ORBIT IN PROGRESS	–				2	7090	5*				1,2

*See Note 1

NOTES

1. The bits and/or D/A's for this display are time-shared with bits already listed and therefore should not be counted as additional bits.
2. Same format as shown for X_1 and X_2.

TABLE 2-11. WALL MAP (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed				Digital Inputs to D/A Converters					
				Zero Display	Full Scale	Units per In.	Notes	Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch Phase													
	X_1	not used during Launch							10				
	Y_1	not used during Launch							10				
	X_2	λ_{pp}	deg	−180	+180			7090	10	$\frac{360}{1023}$	$2 \cdot \frac{360}{1023}$	$2^9 \cdot \frac{360}{1023}$	1
	Y_2	ϕ_{pp}	deg	−40	+40			7090	10	$\frac{80}{1023}$	etc.	etc.	1
Abort and Re-entry Phases													
	X_1	λ_{IP}	deg	−180	+180			7090	10*	$\frac{360}{1023}$	etc.	etc.	1, 2
	Y_1	ϕ_{IP}	deg	−40	+40			7090	10*	$\frac{80}{1023}$	etc.	etc.	1, 2
	X_2	λ_{pp}	deg	−180	+180			7090	10*	$\frac{360}{1023}$	etc.	etc.	1, 2
	Y_2	ϕ_{pp}	deg	−40	+40			7090	10*	$\frac{80}{1023}$	etc.	etc.	1, 2
Orbit Phase													
	X_1	$\lambda_{30\ sec.}$	deg	−180	+180			7090	10*	$\frac{360}{1023}$	etc.	etc.	1, 2
	Y_1	$\phi_{30\ sec.}$	deg	−40	+40			7090	10*	$\frac{80}{1023}$	etc.	etc.	1, 2
	X_2	λ_{pp}	deg	−180	+180			7090	10*	$\frac{360}{1023}$	etc.	etc.	1, 2
	Y_2	ϕ_{pp}	deg	−40	+40			7090	10*	$\frac{80}{1023}$	etc.	etc.	1, 2

*See Note 2

TABLE 2-11. WALL MAP (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES (cont'd)

NOTES

1. The computers zero–offset this data.
2. The bits and/or D/A's for this display are time–shared with bits already listed and therefore should not be counted as additional bits.

TABLE 2-12. DATA QUALITY MONITOR (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES

Where Displayed & Phase	Plot	Quantity	Units	How Displayed				Digital Inputs to D/A Converters					
				Zero Display	Full Scale	Units per In.	Notes	Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch Phase													
	X_1	$\frac{V}{V_R} - \frac{V}{V_R}{}_{norm}$	–	-0.04	+0.04	–	3	7090 (709 data)	10	$\frac{0.02}{1023}$	$2 \cdot \frac{0.02}{1023}$	$2^9 \cdot \frac{0.02}{1023}$	2
	X_2	same	–	-0.04	+0.04	–	3	B-GE	10	$\frac{0.02}{1023}$	etc.	etc.	2
	X_3	same	–	-0.04	+0.04	–	3	7090 (B-GE data)	10	$\frac{0.02}{1023}$	etc.	etc.	2
	X_4	time	Note 1	0	1	1	1,3,4	7090	1	1	–	–	1,4
	X_5	$\gamma - \gamma_{norm}$	deg	-5	+5	1	3	7090 709 data)	10	$\frac{10}{1023}$	etc.	etc.	2
	X_6	$\gamma - \gamma_{norm}$	deg	-5	+5	1	3	B-GE	10	$\frac{10}{1023}$	etc.	etc.	2
	X_7	$\gamma - \gamma_{norm}$	deg	-5	+5	1	3	7090 (B-GE data)	10				
	X_8	spare											
	X_9	δ_1	yes	0	1	1	5	B-GE	1	1	–	–	No D/A Converter Used
	X_{10}	δ_2	yes	0	1	1	5	B-GE	1	1	–	–	
	X_{11}	δ_3	yes	0	1	1	5	B-GE	1	1	–	–	
	X_{12}	γ_n	yes	0	1	1	5	B-GE	1	1	–	–	
	X_{13}	Data source	sel	See Note 20		–	6	7090	3	1	2	4	

NOTES

1. Time marks are supplied by the IBM 7090 with data associated with 10, 20, etc., and 61, 121, etc., seconds after liftoff during the launch and abort phases; 10, 20, etc., and 61, 121, etc., minutes after liftoff during the orbit phase; and every minute after liftoff during the re-entry phase.

TABLE 2-12. DATA QUALITY MONITOR (MCC), SUMMARY OF DISPLAY QUANTITIES, SCALING, AND SOURCES (cont'd)

NOTES (cont'd)

2. The computers zero-offset this data.

3. This recorder is a 7- or 8-pen plotter with selectable paper speeds. If paper moves vertically, X_1 is the right recording. If paper moves horizontally, X_1 is the top recording.

4. This pen makes time marks, supplied by IBM 7090, 10, 20, etc., and 61, 121, etc., seconds after liftoff during launch phase. These time marks are in the form of a pulse or level shift.

5. $\delta_1 = 0$ means computer is integrating rate data to generate track data.
   $\delta_2 = 0$ means computer is differentiating track data to get rate data.
   $\delta_3 = 0$ means computer is differentiating track data for lateral rates only.
   $\gamma_n = 0$ means computer does not have enough information to generate guidance commands.

6. Data source indicated by bits 41, 42, and 83 of message format, Goddard to MCC (table 2-13), as follows:

010	Raw radar	110	IP 709, Azusa input
100	B-GE data	111	IP 709, FPS-16 input

TABLE 2-13. GODDARD TO MERCURY CONTROL CENTER, MESSAGE FORMAT

Odd Frame			Even Frame		
Bit No.	Plot	Display	Bit No.	Plot	Display
1-10	X_7	Data Quality Monitor	1-10	X_7	Data Quality Monitor
11-20	X_5	Data Quality Monitor	11-20	X_5	Data Quality Monitor
21-30	X_3	Data Quality Monitor	21-30	X_3	Data Quality Monitor
31-40	X_1	Data Quality Monitor	31-40	X_1	Data Quality Monitor
41	X_{13}	Data Quality Monitor	41	X_{13}	Data Quality Monitor
42	X_{13}	Data Quality Monitor	42	X_{13}	Data Quality Monitor
43-52	Y_2	Wall Map	43-52	Y_2	Wall Map
53-62	X_2	Wall Map	53-62	X_2	Wall Map
63-72	Y_1	Wall Map	63-72	Y_1	Wall Map
73-82	X_1	Wall Map	73-82	X_1	Wall Map
83	X_{13}	Data Quality Monitor	83	X_{13}	Data Quality Monitor
84	---	1 = Odd Frame Data	84	---	1 = Odd Frame Data
85	---	1 = Even Frame Data	85	---	1 = Even Frame Data
86-89	X_1 Units Secs.	Wall Digital Display	86-89	X_1 Units Secs.	Retrofire Controller's Console
90-92	X_1 Tens Secs.	Wall Digital Display	90-92	X_1 Tens Secs.	
93-96	X_1 Units Mins	Wall Digital Display	93-96	X_1 Units Mins	
97-99	X_1 Tens Mins	Wall Digital Display	97-99	X_1 Tens Mins	
100-103	X_1 Units Hrs	Wall Digital Display	100-103	X_1 Units Hrs	
104-105	X_1 Tens Hrs	Wall Digital Display	104-105	X_1 Tens Hrs	
106-109	X_2 Units	Wall Digital Display	106-109	X_2 Units Secs	
110	X_2 Tens	Wall Digital Display	110-112	X_2 Tens Secs	
111-114	X_1 Units Mins	Recovery Status Monitor	113-116	X_2 Units Mins	
115-117	X_1 Tens Mins	Recovery Status Monitor	117-119	X_2 Tens Mins	Retrofire Controller's Console

TABLE 2-13. GODDARD TO MERCURY CONTROL CENTER, MESSAGE FORMAT (cont'd)

Odd Frame			Even Frame		
Bit No.	Plot	Display	Bit No.	Plot	Display
118-121	X_1 Units Hrs	Recovery Status Monitor	120-123	X_2 Units Hrs	Retrofire Controller's Console
122-123	X_1 Tens Hrs	Recovery Status Monitor	124-125	X_2 Tens Hrs	Retrofire Controller's Console
124		Busy Bit	126		Busy Bit
125-128	X_3 Units Mins	Recovery Status Monitor	127-130	X_3 Units Secs.	Retrofire Controller's Console
129-131	X_3 Tens Mins		131-133	X_3 Tens Secs.	
132-135	X_3 Units Deg		134-137	X_3 Units Mins	
136-139	X_3 Tens Deg		138-140	X_3 Tens Mins	
140	X_3 Sign N-S		141-144	X_3 Units Hrs	
141-144	X_2 Units Mins		145-146	X_3 Tens Hrs	
145-147	X_2 Tens Mins		147-150	X_4 Units Secs.	
148-151	X_2 Units Deg		151-153	X_4 Tens Secs.	
152-155	X_2 Tens Deg		154-157	X_4 Units Mins	
156	X_2 hundreds Deg		158-160	X_4 Tens Mins	
157	X_2 Sign E-W	Recovery Status Monitor	161-164	X_4 Units Hrs	
158		Busy Bit	165-166	X_4 Tens Hrs	Retrofire Controller's Console
159	X_1 Go	Flight Dynamics Officer's Console	167		Busy Bit
160	X_1 No-go		168-171	X_5 Units Secs.	Retrofire Controller's Console
161-164	X_2 10^{-1}		172-174	X_5 Tens Secs.	
165-168	X_2 10^0		175-178	X_5 Units Mins	
169-172	X_2 10^1		179-181	X_5 Tens Mins	
173-176	X_2 10^2		182-185	X_5 Units Hrs	
177-180	X_3 10^{-2}		186-187	X_5 Tens Hrs	
181-184	X_3 10^{-1}	Flight Dynamics Officer's Console	188-191	X_6 Units Secs.	Retrofire Controller's Console

TABLE 2-13. GODDARD TO MERCURY CONTROL CENTER, MESSAGE FORMAT (cont'd)

Odd Frame			Even Frame		
Bit No.	Plot	Display	Bit No.	Plot	Display
185-188	X_3 10^0	Flight Dynamics Officer's Console	192-194	X_6 Tens Secs	Retrofire Controllers Console
189-192	X_3 10^1	Flight Dynamics Officer's Console	195-198	X_6 Units Mins	
193	X_3 Sign + −	Flight Dynamics Officer's Console	199-201	X_6 Tens Mins	
194	–	Busy Bit	202-205	X_6 Units Hrs	
195-198	X_4 10^{-1}	Flight Dynamics Officer's Console	206-207	X_6 Tens Hrs	Retrofire Controller's Console
199-202	X_4 10^0		208	–	Busy Bit
203-206	X_4 10^1		209-212	X_7 Units Secs	Retrofire Controller's Console
207-210	X_5 10^0		213-215	X_7 Tens Secs	
211-212	X_5 10^1		216-219	X_7 Units Mins	
213-216	X_6 10^{-4}		220-222	X_7 Tens Mins	
217-220	X_6 10^{-3}		223-226	X_7 Units Hrs	
221-224	X_6 10^{-2}		227-228	X_7 Tens Hrs	
225-228	X_6 10^{-1}		229-232	X_8 Units Secs	
229-230	X_6 10^0	Flight Dynamics Officer's Console	233-235	X_8 Tens Secs	
231	–	Busy Bit	236	X_8 Adv. Ret.	
232-256	–	Spares	237-240	X_8 Units Mins	
			241-243	X_8 Tens Mins	
			244	X_8 Adv Ret	
			245-248	X_8 Units Hrs	
			249-250	X_8 Tens Hrs	
			251	X_8 Adv Ret	
			252-254	X_9 A – H	
			255-256	X_9 1 – 3	Retrofire Controller's Console

TABLE 2-13. GODDARD TO MERCURY CONTROL CENTER, MESSAGE FORMAT (cont'd)

Odd Frame			Even Frame		
Bit No.	**Plot**	**Display**	**Bit No.**	**Plot**	**Display**
257		Busy Bit	257		Busy Bit
258-267	Y_2	Plot Board IV	258-267	Y_2	Plot Board IV
268-277	X_2	Plot Board IV	268-277	X_2	Plot Board IV
278-287	Y_1	Plot Board IV	278-287	Y_1	Plot Board IV
288-297	X_1	Plot Board IV	288-297	X_1	Plot Board IV
298		Busy Bit	298		Busy Bit
299-308	Y_1	Plot Board III	299-308	Y_1	Plot Board III
309-318	X_1, X_2	Plot Board III	309-318	X_1, X_2	Plot Board III
319-328	Y_2	Plot Board III	319-328	Y_2	Plot Board III
329-338	Y_2	Plot Board II	329-338	Y_2	Plot Board II
339		Busy Bit	339		Busy Bit
340-349	X_1, X_2	Plot Board II	340-349	X_1, X_2	Plot Board II
350-359	Y_1	Plot Board II	350-359	Y_1	Plot Board II
360-369	Y_1	Plot Board I	360-369	Y_1	Plot Board I
370-379	X_1	Plot Board I	370-379	X_1	Plot Board I
380		Busy Bit	380		Busy Bit
381-390	Y_2	Plot Board I, Spare	381-390	Y_2	Plot Board I, Spare
391-400	X_2	Plot Board I, Spare	391-400	X_2	Plot Board I, Spare
401	Time Mark	Plot Boards I, II, III, & IV and Data Quality Monitor X_4	401	Time Mark	Plot Boards I, II, III, & IV and Data Quality Monitor X_4
402-408		Spares	402-408		Spares

Note

Least significant bit of each quantity above is transmitted first. See tables 2-1 to 2-12 for summary of display quantities, scaling, and sources.

TABLE 2-14. BURROUGHS—GE COMPLEX TO MERCURY CONTROL CENTER, MESSAGE FORMAT

Bit No.	Plot	Display
1	X_9	Data Quality Monitor
2	X_{10}	Data Quality Monitor
3	X_{11}	Data Quality Monitor
4	X_{12}	Data Quality Monitor
5	---	Not Used
6	X_1	Missile Telemetry Monitor Console
7	X_2*	Missile Telemetry Monitor Console
8	X_1*	Flight Dynamics Officer's Console
9-18	X_6	Data Quality Monitor
19-28	X_2	Data Quality Monitor
29-38	Y_{1B}	Plot Board III
39-48	X_{1B}, X_{2B}	Plot Board III
49-58	Y_{2B}	Plot Board III
59-68	Y_{1A}	Plot Board III
69-78	X_1, X_2	Plot Board II
79-88	Y_2	Plot Board II
89-98	Y_1	Plot Board II
99-108	Y_1	Plot Board I
109-118	X_1	Plot Board I
119-128	X_{1A}, X_{2A}	Plot Board III

*Bit 8 is the Go-No-Go recommendation from the B-GE Guidance Computer. (Binary 1 indicates go, and binary 0 indicates no-go.) The go-no-go recommendation is not displayed until Sustainer Engine Cutoff has occurred, indicated by a binary 1 in bit 7. The signal indicating that SECO has occurred (binary 1 output) is utilized to condition both the go and no-go signals so that neither will be displayed until SECO has occurred.

Note: Most significant bit is transmitted first. See tables 2-1 to 2-12 for summary of display quantities, scaling, and source.

TABLE 2-15. MERCURY CONTROL CENTER (TELEMETRY EVENT TRANSMITTING BUFFER) TO HIGH-SPEED RETRANSMITTERS, MESSAGE FORMAT

Bits	Quantity	Comment
1–20	Capsule elapsed time reading (Binary-coded decimal - as follows) Bits 1 – 2 Tens of hours Bits 3 – 6 Units of hours Bits 7 – 9 Tens of minutes Bits 10 – 13 Units of minutes Bits 14 – 16 Tens of seconds Bits 17 – 20 Units of seconds	
21–40	Retrofire mechanism setting (Binary-coded decimal - as follows) Bits 21 – 22 Tens of hours Bits 23 – 26 Units of hours Bits 27 – 29 Tens of minutes Bits 30 – 33 Units of minutes Bits 34 – 36 Tens of seconds Bits 37 – 40 Units of seconds	
41	Capsule elapsed time not valid	1=not valid
42	Retrofire mechanism setting not valid	1=not valid
43	Liftoff	1=has occurred
44	Staging	1=has occurred
45	Escape tower separated	1=has occurred
46	Tower escape rockets fired	1=has occurred
47	Capsule separated from sustainer	1=has occurred
48	One of three posigrades fired	1=has occurred
49	Two of three posigrades fired	1=has occurred
50	Three of three posigrades fired	1=has occurred
51	Abort sequence initiated	1=has occurred
52	Retro 1 fired	1=has occurred
53	Retro 1 and 2 fired	1=has occurred
54	Retro 1, 2, and 3 fired	1=has occurred
55	Spare	1=was commanded
56	Burroughs–GE data selected	0=Azusa/FPS-16 data selected

TABLE 2-15. MERCURY CONTROL CENTER (TELEMETRY EVENT TRANSMITTING BUFFER) TO HIGH-SPEED RETRANSMITTERS, MESSAGE FORMAT (cont'd)

Bits	Quantity	Comment
57	Liftoff signal manually reversed	1=was reversed
58	Staging signal manually reversed	1=was reversed
59	Escape tower separated signal manually reversed	1=was reversed
60	Tower escape rockets fired manually reversed	1=was reversed
61	Capsule separated from sustainer manually reversed	1=was reversed
62	One of three posigrades fired manually reversed	1=was reversed
63	Two of three posigrades fired manually reversed	1=was reversed
64	Three of three posigrades fired manually reversed	1=was reversed
65	Abort sequence initiated manually reversed	1=was reversed
66	Retro 1 fired manually reversed	1=was reversed
67	Retro 1 and 2 fired manually reversed	1=was reversed
68	Retro 1, 2, and 3 fired manually reversed	1=was reversed
69	Abort phase has started	1=has started
70	Orbit phase has started	1=has started
71	Spare	
72	Parity for previous 71 bits	1=An even number of 1's in the previous 71 bits.

TABLE 2-16. BURROUGHS-GE COMPUTER TO HIGH-SPEED RETRANSMITTER, MESSAGE FORMAT

Computer Word	Data Quantities
1	Discrete word (8 bits within the 24-bit word) Bit 14 – Flag δ_1 Bit 15 – Flag δ_2 Bit 16 – Flag ∂_3 Bit 17 – Flag γ_η Bit 18 – 2-inch liftoff signal Bit 19 – Booster engine cutoff (BECO) Bit 20 – Sustainer engine cutoff (SECO) Bit 21 – Go-no-go indication
2	Inertial velocity $\dot{\zeta}$ (sign + 23 bits, binary scaling + 1) Multiply by 26529.807 (decimal) to get ft/sec.
3	Inertial velocity $\dot{\eta}$ (sign + 23 bits, binary scaling + 1) Multiply by 26529.807 (decimal) to get ft/sec.
4	Inertial velocity $\dot{\xi}$ (sign + 23 bits, binary scaling + 1). Multiply by 26529 807 (decimal) to get ft/sec.
5	Time from 2-inch motion (sign + 23 bits, binary scaling + 9) T_E. Count of time increments from liftoff. Each increment equals 1 second.
6	Inertial position ζ (sign + 23 bits, binary scaling + 1). Multiply by 2×10^7 to get ft.
7.	Inertial position η (sign + 23 bits, binary scaling + 1). Multiply by 2×10^7 to get ft.
8	Inertial position ξ (sign + 23 bits, binary scaling + 1). Multiply by 2×10^7 to get ft.
9	Checksum of words 1 through 8 (sign + 23 bits). Sum is formed in order in which words are loaded, disregarding overflow and scaling.

TABLE 2-16. BURROUGHS-GE COMPUTER TO HIGH-SPEED RETRANSMITTER. MESSAGE FORMAT (cont'd)

Computer Word	Data Quantities
	Words 10 through 21 are scaled as integers between 0 and $2^{10} - 1$ with binary scaling of + 23.
10	$\Gamma - \Gamma$ nom (10 bits, positions 14 through 23)
11	$V / V_r - (V / V_r)$ nom (10 bits, positions 14 through 23)
12	Yaw velocity error, V_y (10 bits, positions 14 through 23)
13	Time to go to SECO, T_η (10 bits, positions 14 through 23)
14	Predicted height of insertion, h_{ins} (10 bits, positions 14 through 23)
15	Inertial velocity, V (10 bits, positions 14 through 23)
16	Horizontal range, d (10 bits, positions 14 through 23)
17	Cross-range deviation, $y - y_{nom}$ (10 bits, positions 14 through 23)
18	Altitude, h (10 bits, positions 14 through 23)
19	Flight path angle, Γ (10 bits, positions 14 through 23)
20	Velocity ratio V / V_r (10 bits, positions 14 through 23)
21	Elapsed time, T_e (10 bits, positions 14 through 23)

TABLE 2-17. IMPACT PREDICTOR 709 COMPUTER TO HIGH-SPEED RETRANSMITTER, MESSAGE FORMAT

Word	Quantity
1	Time of data, referenced to first motion; count of 0.1 second units in 4-bit BCD.
2	Position vector X
3	Position vector Y
4	Position vector Z
5	Velocity vector $\dot{X}$
6	Velocity vector $\dot{Y}$
7	Velocity vector $\dot{Z}$
8	Checksum (logical checksum of words 1 through 7)

NOTES

1. Sign bit in word 1 indicates Azusa or FPS-16 input.
2. Units of position vectors X, Y, and Z are canonical units of distance (CUD), where one CUD is equal to 20,926,435 ft.
3. Units of velocity vectors $\dot{X}$, $\dot{Y}$, and $\dot{Z}$ are:

$$\text{Canonical units of velocity (CUV)} = \frac{\text{CUD}}{\text{CUD}} \ \text{ft/sec.}$$

where the canonical unit of time (CUT) equals 806.832 seconds.

TABLE 2-18. RAW RADAR DATA TO HIGH SPEED RETRANSMITTER, MESSAGE FORMAT

Bit No.	Quantity	Bit No.	Quantity	Bit No.	Quantity
1	Sync	28	E_4	55	A_{11}
2	R_1	29	Sync	56	E_{11}
3	0	30	R_8	57	Sync
4	0	31	A_5	58	R_{15}
5	Sync	32	E_5	59	A_{12}
6	R_2	33	Sync	60	E_{12}
7	0	34	R_9	61	Sync
8	0	35	A_6	62	R_{16}
9	Sync	36	E_6	63	A_{13}
10	R_3	37	Sync	64	E_{13}
11	0	38	R_{10}	65	Sync
12	On track Bit	39	A_7	66	R_{17}
13	Sync	40	E_7	67	A_{14}
14	R_4	41	Sync	68	E_{14}
15	A_1	42	R_{11}	69	Sync
16	E_1	43	A_8	70	R_{18}
17	Sync	44	E_8	71	A_{15}
18	R_5	45	Sync	72	E_{15}
19	A_2	46	R_{12}	73	Sync
20	E_2	47	A_9	74	R_{19}
21	Sync	48	E_9	75	A_{16}
22	R_6	49	Sync	76	E_{16}
23	A_3	50	R_{13}	77	Sync
24	E_3	51	A_{10}	78	R_{20}
25	Sync	52	E_{10}	79	A_{17}
26	R_7	53	Sync	80	E_{17}
27	A_4	54	R_{14}		

Notes

1. Bit 1 of each quantity is the least significant bit.
2. The range, azimuth, and elevation quantities are digital values. The units of each quantity are such that the quantitization represented by 1 bit is :

   For range, 1 bit = 1.000064 yd.
   For azimith, 1 bit = 0.048828125 mil
   For elevation, 1 bit = 0.048828125 mil

TABLE 2-19. EACH IBM 7090 TO ITS ASSOCIATED PLOT BOARD AT GODDARD, MESSAGE FORMAT

Bits	Plot	Display
1 – 10	Y2	Plot board
11 – 20	X2	Plot board
21 – 30	Y1	Plot board
31 – 40	X1	Plot board
Note: Least significant bit of each quantity is transmitted first.		
41		Left arm upper pen, 1 = lift 0 = plot
42		Left arm lower pen, 1 = lift 0 = plot & offset
43		Right arm upper pen, 1 = lift 0 = plot
44		Right arm lower pen, 1 = lift 0 = plot & offset
45		Left arm standby, 1 = standby
46		Right arm standby, 1 = standby
47		Spare
48		Spare

TABLE 2-20. TELEMETRY EVENT BUFFER TO IBM 709, BERMUDA, MESSAGE FORMAT

Bits	Quantity	Comment
1 - 20	Capsule elapsed time reading (binary-coded decimal - as follows) bits 1 - 2 tens of hours bits 3 - 6 units of hours bits 7 - 9 tens of minutes bits 10 - 13 units of minutes bits 14 - 16 tens of seconds bits 17 - 20 units of seconds	
21 - 24	Spares	Zeros sent in spare positions.
25 - 44	Retrofire mechanism setting (binary-coded decimal - as follows) bits 25 - 26 tens of hours bits 27 - 30 units of hours bits 31 - 33 tens of minutes bits 34 - 37 units of minutes bits 38 - 40 tens of seconds bits 41 - 44 units of seconds	
45 - 47	Spares	Zeros sent in spare positions.
48	Change displays X_2 and X_3 to X_{2A} and X_{3A}	1 = is commanded
49	Capsule released from sustainer	1 = has occurred
50	One of three posigrades fired	1 = has occurred
51	Two of three posigrades fired	1 = has occurred
52	Three of three posigrades fired	1 = has occurred
53	Abort sequence initiated	1 = has occurred

TABLE 2-20. TELEMETRY EVENT BUFFER TO IBM 709, BERMUDA, MESSAGE FORMAT (cont'd)

Bits	Quantity	Comment
54	Retro 1 fired	1 = has occurred
55	Retro 1 and 2 fired	1 = has occurred
56	Retro 1, 2, and 3 fired	1 = has occurred
57	Capsule released from sustainer, manually reversed	1 = was reversed
58	One of three posigrades fired, manually reversed	1 = was reversed
59	Two of three posigrades fired, manually reversed	1 = was reversed
60	Three of three posigrades fired, manually reversed	1 = was reversed
61	Abort sequence initiated, manually reversed	1 = was reversed
62	Retro 1 fired, manually reversed	1 = was reversed
63	Retro 1 and 2 fired, manually reversed	1 = was reversed
64	Retro 1, 2, and 3 fired, manually reversed	1 = was reversed

TABLE 2-21. IBM 709 TO DISPLAYS AT BERMUDA, MESSAGE FORMAT

	Odd Frame			Even Frame	
Bit No.	Plot	Display	Bit No.	Plot	Display
11 – 10	Y_2	Plot Board I	1 – 10	Y_2	Plot Board I
11 – 20	X_2	Plot Board I	11 – 20	X_2	Plot Board I
21 – 30	Y_1	Plot Board I	21 – 30	Y_1	Plot Board I
31 – 40	X_1	Plot Board I	31 – 40	X_1	Plot Board I
41	– –	1 =Odd Frame Data	41	– –	1 = Odd Frame Data
42	– –	1 = Even Frame Data	42	– –	1 = Even Frame Data
43 – 58	h	Flight Dynamics Officer's Console	43 – 62	GMTRC	Flight Dynamics Officer's Console
59 – 75	γ	Flight Dynamics Officers Console			43 – 46 units of seconds
76 – 93	V/V_R	Flight Dynamics Officer's Console			47 – 49 tens of seconds
94	ICTRC	Seconds, advance or retard			50 – 53 units of minutes
95	ICTRC	Minutes, advance or retard			54 – 56 tens of minutes
96	ICTRC	Hours, advance or retard			57 – 60 units of hours
					61 – 62 tens of hours
			63 – 82	ECTRC	Flight–Dynamic Officer's Console
					63 – 66 units of seconds
					67 – 69 tens of seconds
					70 – 73 units of minutes
					74 – 76 tens of minutes
					77 – 80 units of hours
					81 – 82 tens of hours
				Recovery Area	Flight Dynamics Officer's Console
					83 – 85 A – E
					86 – 87 – 1, 2, 3

TABLE 2-21. IBM 709 TO DISPLAYS AT BERMUDA, MESSAGE FORMAT (cont'd)

	Odd Frame			Even Frame	
Bit No.	Plot	Display	Bit No.	Plot	Display
			88	Go	Flight Dynamics Officer's Console
			89	No – Go	Flight Dynamics Officer's Console
			90 – 96	– – –	Spares

NOTE

Least significant bit of each quantity above is transmitted first. See table 2–22 for summary of display quantities, scaling, and sources.

TABLE 2-22. PLOT BOARD 1 (BERMUDA), SUMMARY OF DISPLAY QUANTITIES AND SCALING

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	Full Scale	Units per In.	Notes	Digital Inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
Launch Phase													
	X_1	λ_1	deg	–75	+75	5		IBM 709	10	$\frac{150}{1023}$	$2 \cdot \frac{150}{1023}$	$2^9 \cdot \frac{150}{1023}$	1,3
	Y_1	ϕ_1	deg	–80	+40	4		IBM 709	10	$\frac{120}{1023}$	etc.	etc.	1,3
	X_2	V/V_R	–	0.86	1.01	0.005		IBM 709	10	$\frac{0.15}{1023}$	etc.	etc.	1,3
	Y_2	γ	deg	–0.5	+2.5	0.1		IBM 709	10	$\frac{3}{1023}$	etc.	etc.	1,3
After Retrofire (Aborted Flight)													
	X_1	λ_{IP}	deg	–75	+75	5		IBM 709	10*	$\frac{150}{1023}$	$2 \cdot \frac{150}{1023}$	$2^9 \cdot \frac{150}{1023}$	1,2,3
	Y_1	ϕ_{IP}	deg	–80	+40	4		IBM 709	10*	$\frac{120}{1023}$	etc.	etc.	1,2,3
	X_2	λ_{PP}	deg	–75	+75	5		IBM 709	10*	$\frac{150}{1023}$	etc.	etc.	1,2,3
	Y_2	ϕ_{PP}	deg	–80	+40	4		IBM 709	10*	$\frac{120}{1023}$	etc.	etc.	1,2,3

ϕ_1 and λ_1 is impact point for immediate retrofire.

NOTES

1. The computer zero-offsets this data.
*2. The bits and D/A's for this display are time-shared with bits listed above and, therefore, are not to be counted as additional bits.
3. Time marks are made with each plot at a 1-second interval. These marks are generated from the even frame bit in the 709 output message (bit 42).

TABLE 2-23. FLIGHT DYNAMICS OFFICER'S CONSOLE (BERMUDA), SUMMARY OF DISPLAY QUANTITIES AND SCALING

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	How Displayed: Full Scale	How Displayed: Units per In.	How Displayed: Notes	Digital inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
	X_1	h	naut.mi.	0.0	0.9	0.1		IBM 709	4	0.1	0.2	0.8	
		h	naut.mi.	0	9	1		↑	4	1	2	8	
		h	naut. mi.	0	90	10			4	10	20	80	
		h	naut.mi	0	900	100			4	100	200	800	
	X_{2A}	γ	deg	0.00	0.90	0.01			4	0.01	0.02	0.08	
		γ	deg	0.0	0.9	0.1			4	0.1	0.2	0.8	
		γ	deg	0	9	1			4	1	2	8	
		γ	deg	0	90	10			4	10	20	80	
		γ	±	+	–	1			1	1	–	–	
	X_{2B}	Δt_r	sec.	0	9	1	1		4	1	2	8	
		Δt_r	sec.	0	50	10			4	10	20	80	2
		Δt_r	min	0	9	1			4	1	2	8	
		Δt_r	min	0	99	10			4	10	20	80	
		±	±	+	–	1			1				
	X_{3A}	V/V_R	–	0.0000	0.0009	0.0001			4	0.0001	0.0002	0.0008	
		V/V_R	–	0.000	0.009	0.001		↓	4	0.001	0.002	0.008	
		V/V_R	–	0.00	0.09	0.01		IBM 709	4	0.01	0.02	0.08	

TABLE 2-23. FLIGHT DYNAMICS OFFICER'S CONSOLE (BERMUDA), SUMMARY OF DISPLAY QUANTITIES AND SCALING (cont'd)

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	Full Scale	Units per In.	Notes	Digital inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
		V/V_R	–	0.0	0.9	0.1		IBM 709	4	0.1	0.2	0.8	
		V/V_R	–	0	3	1			2	1	–	2	
	X_{3B}	ICTRC	sec.	0	9	1	1		4	1	2	8	
		ICTRC	sec.	0	50	10			4	1	2	8	2
		Retard Setting	Retard Secs.	Green Advance	Red Retard	1			1	1	–	–	
		ICTRC	min	0	9	1			4	1	2	8	
		ICTRC	min	0	50	10			4	1	2	8	2
		Retard Setting	Retard min	Green Advance	Red Retard	1			1	1	–	–	
		ICTRC	hours	0	3	1			2	1	–	2	
		Retard Setting	Retard hours	Green Advance	Red Retard	1			1	1	–	–	
	X_4	GMTRC	sec	0	9	1			4	1	2	8	
			sec	0	50	10			3	10	20	40	
			min.	0	9	1			4	1	2	8	
			min.	0	50	10			3	10	20	40	
			hour	0	9	1			4	1	2	8	
		GMTRC	hour	0	20	10			2	10	–	20	
	X_5	ECTRC	sec	0	9	1	3	IBM 709	4	1	2	8	

TABLE 2-23. FLIGHT DYNAMICS OFFICER'S CONSOLE (BERMUDA), SUMMARY OF DISPLAY QUANTITIES AND SCALING (cont'd)

Where Displayed & Phase	Plot	Quantity	Units	How Displayed: Zero Display	Full Scale	Units per In.	Notes	Digital inputs to D/A Converters: Data Source	No. Bits	First Bit	Second Bit	Last Bit	Notes
		ECTRC	sec.	0	50	10		IBM 709	3	10	20	40	
			min.	0	9	1			4	1	2	8	
			min.	0	50	10			3	10	20	40	
			hour	0	9	1			4	1	2	8	
		ECTRC	hour	0	20	10			2	10	-	20	
	X_6	Recovery area	no.	A	E	1	4		3	1	2	4	5
		Recovery area	no.	-	3	1	4		2	1	2	-	5
	X_7	Go Recommendation	go,	0	Go	1			1	1	-	-	
		No-go recomm.	No Go	0	No Go	1		IBM 709	1	1	-	-	

NOTES

1. Display X_{2A} is replaced by X_{2B}, and display X_{3A} is replaced by X_{3B} upon receipt by IBM 709 computer of change-display signal (bit 48 of telemetry event buffer message).
2. This 4-bit quantity is limited by IBM 709 computer to a maximum value of 50 (decimal), when indicating tens of seconds or minutes in displays X_{2B} and X_{3B}.
3. ECTRC is also displayed on capsule communicator's console.
4. See note 5, table 2-6. Right side indicator uses only letters A – E at Bermuda.
5. The bits and D/A's for this display are time-shared with bits listed above and, therefore, are not counted as additional bits.

CHAPTER 3

GODDARD COMPUTER FUNCTIONS

3.1 GENERAL

During the launch and abort phase, all the available inputs are used: high-speed, teletype, and paper tape. During a re-entry phase following an early abort phase, raw radar data transmitted via the IP 709 complex over high-speed data lines is used in computing re-entry parameters. During the orbit phase, or a re-entry phase following an orbit phase, raw radar data transmitted via teletype is used in computing orbit and re-entry parameters. Telemetry and human decision data, during all phases, is transmitted from the Mercury Control Center to Goddard via the high-speed lines.

3.2 INPUTS TO GODDARD

The real-time data inputs to the Goddard IBM 7090 computers are of two types, high-speed data inputs and low-speed data inputs. In addition to these real-time inputs, a paper tape input is available for inserting certain discrete events, as well as station parameters, into the computer.

3.2.1 High-Speed Input Data

Data from two sources at Cape Canaveral is received over high-speed data lines. Two such input lines from the Burroughs—General-Electric complex and two lines from the input predictor 709 complex provide duplicate inputs from each of these sources. A transmission check is made by comparing the two sets of data received at Goddard. This information is detailed in figures 2-15 to 2-17 and table 2-15.

The AZUSA beacon is located in the launch vehicle (not the capsule) and thus is used for an input to the IP 709 for vehicle impact prediction. After capsule separation occurs, therefore, AN/FPS-16 raw radar is manually selected for use by Goddard.

The B-GE System also tracks the launch vehicle and therefore does not give capsule position data after the capsule separates from the launch vehicle.

The high-speed input data is fed directly into the data communication channel (DCC) of the Goddard computers in 8-bit bytes. The DCC places the eight bits into the low order positions (28-35) of one word designated by the line's channel address register and increments the address register by 1. After one subframe consisting of 192 (= 8 x 24) bits of data has been inserted into a block of 24 consecutive words of storage, the DCC resets the line's channel address register and interrupts the program, which in turn moves the data out of this block for processing and time-tags it.

3.2.2 Low-Speed Teletype Data Input

During each pass of the capsule over a radar site, position information is sent to Goddard every six seconds according to the message format shown in figure 3-1. The units for the range, azimuth, and elevation are listed in table 2-18. Time is specified in Greenwich mean time in hours, minutes, and seconds, and negative elevation angles of observations below the horizontal plane appear in complemented form ($-10^{o} = 350^{o}$, $-8^{o} = 352^{o}$.)

Two types of radars are used by the Mercury radar sites, Verlort and FPS-16. The Verlort has greater range capability; the FPS-16 is more accurate at close range.

For a site having both types of radars, the normal tracking and data transmission procedure is as follows. The Verlort starts its active tracking first, and a manual switch selects the Verlort data for teletype transmission. As the capsule comes within range of the FPS-16 radar, the switch is turned to select FPS-16 data while the Verlort continues tracking. When the capsule goes out of FPS-16 range, the data transmitter is switched back to Verlort. All the data transmitted as well as Verlort data for the entire range is recorded on paper tape in 5-channel teletype code. If the initial transmission of data is unsatisfactory, Goddard may request retransmission. In this case, a site equipped with both Verlort and AN/FPS-16 radars transmits the Verlort data for the entire range instead of repeating the initial transmission with AN/FPS-16 data in the middle.

The 16 teletype input lines all present TTY characters to the data communications channel (DCC) at the rate of six characters per second. The DCC accepts one 5-bit character at a time and places it in the low order positions (31 - 35) of one 7090 word according to the channel address register of that line and then increments the channel address register by 1. When six characters have been placed in six consecutive locations of storage, the DCC resets the channel address register of this line and causes an interrupt in the program. The program then picks up the TTY characters, each with a leading zero bit, packs them into a 36-bit word, and stores the word in a 10-word block set aside for this particular line. When this block is filled up with new data, it is presented to the input program for processing.

3.2.3 Paper Tape Input

Certain discrete quantities not needed on a real-time basis are manually inserted into the Goddard computers by means of paper tape. These quantities are monitored from the incoming teletype data, repunched in a prescribed teletype format, and inserted in the paper tape reader connected to the DDC.

The following quantities are those that are inserted in such a manner:

a. Greenwich mean time of liftoff received via low-speed teletype from Cape Canaveral during launch.

b. Greenwich mean time of firing of each retro-rocket from any tracking station during flight.

c. Elapsed capsule time and retrofire clock setting with associated Greenwich mean time sent from each tracking station after the capsule passes out of range.

d. Meteorological data for each site, which must be sent to Goddard via the teletype lines at least one hour before launch time. This data is not updated after that time. If no data is received from a particular site, standard atmosphere data is used.

e. Radar measurements of the boresight azimuth and elevation angle from each radar station a few hours before launch time.

3.3 DATA PROCESSING

3.3.1 Input Data

Both Goddard IBM 7090 Systems accept telemetry, human decision, and capsule position and velocity data in a variety of forms, as described in paragraph 3.2.

Telemetry data indicates subphase of the mission and mission status.

3.3.2 Data Handling

3.3.2.1 Launch and Abort Phases

During launch, the computing cycle is 500 milliseconds, which corresponds to the nominal message frame repetition time from the B-GE complex. The IP 709 data, when manually selected, is received at a message frame repetition time of 400 milliseconds. Therefore, in every fourth IBM 7090 computing cycle, one IP 709 message is discarded in favor of a more timely message.

The data from the high-speed sources is edited for transmission errors, and information for the data quality monitor (table 2-12) is computed from both inputs, B-GE and IP-709 or AN/FPS-16 raw radar.

A data-source-select signal from the Mercury Control Center determines the data source used for the computation of data for digital display and plot board displays.

If AN/FPS-16 raw radar is manually selected in lieu of IP 709, it is accepted, edited, and smoothed so that the computing cycle can be maintained at 1/2 second.

3.3.2.2 Orbit and Re-entry Phases

During orbit and re-entry, the computing cycle is such that complete display data (two frames) is sent to the Mercury Control Center as follows:

During orbit: Every 12 seconds
During re-entry: Every 6 seconds

The raw radar information received by teletype is edited, and the best set of observations is chosen from the input set before processing by differential correction.

3.3.2.3 Output Information

Output information, except downrange and cross-range distance, is computed in the co-ordinate system which is applicable to the particular input source during all phases of the mission. For downrange and cross-range distance, these co-ordinate systems are transformed to a topocentric system with the origin at the pad.

3.3.2.3.1 Normal Launch

Launch computations which last from liftoff to passage beyond radar range of Cape Canaveral may be divided into two phases, normal and abort. The normal launch may be divided into three subphases: liftoff to tower separation, tower separation to capsule separation, and post capsule separation. In each subphase, a continuous prediction of impact point and time for retrofire is made in the event of an abort situation. The Mercury Co-ordinate System is used for impact point predictions and, as such, Burroughs—General-Electric and IP 709 data are transformed to this system.

In the first subphase, impact point is computed by solving elliptic equations to the ground. After tower release, the impact point is computed in two ways in each cycle. The first method is based on the possibility of an immediate abort and retrofire in 30 seconds. The second impact point is computed assuming retrofire at maximum range (450,000 feet). After capsule separation, a go-no-go recommendation is made in addition to computing impact point. Five seconds after capsule separation, a final go-no-go recommendation is made. Orbit capability is computed so that the computer is ready to enter the orbit phase unless an abort command is received from the Mercury Control Center.

3.3.2.3.2 Abort Phase

The abort phase is entered if an abort is commanded by the Mercury Control Center. Raw data is normally processed in this phase. The data is edited, smoothed, and converted to vector position and velocity. Time for retrofire and the associated impact point are computed.

If raw data is not available, the abort landing point is computed using the previous set of processed B-GE or IP 709 data. This is necessary since the capsule is being tracked during an abort, and only launch vehicle data is available; in this case, the vehicle velocity is incremented by the posigrade firing velocity. Abort calculations are made until retrofire signals have been received, at which time the re-entry phase is entered.

3.3.2.3.3 Orbit

Two macroprogramming systems comprise the orbit phase of the mission. The first, known as the orbit prediction macro system, has as its prime function the development of an output table of predicted positions and corresponding velocities of the capsule during its flight. The input consists of a set of orbital elements or parameters which are used in the solution of equations which determine the capsule's orbit.

The second system, known as the differential correction macro system, has as its major purpose the determination of the instantaneous orbit parameters. The input to this system consists of edited radar observations as well as an orbit prediction table covering the time interval spanning the observations and based on the previous set of orbit parameters. A series of corrections to the orbit elements are calculated, which when added to the previous elements produce the instantaneous orbit elements.

3.3.2.3.4 Re-entry

In the re-entry phase, the orbit differential correction process is used for observations which are above 450,000 feet to improve predictions of the re-entry trajectory. No observations prior to the time of burnout of the retro-rockets are included in this process. Numerical differential correction is utilized when observations below 450,000 feet are included in the correction process. Each time an updated re-entry trajectory is established, the predicted landing point of the capsule is computed.

3.4 OUTPUT DATA

3.4.1 Functions

The function of the output section is to convert the computed orbital data into the formats required for transmission to the Mercury Control Center, radar sites, Goddard, and Bermuda displays. The output is transmitted by the Mercury data communications channel in the following manner.

The TTY lines transmit data at the rate of six characters per second, with one character per 7090 word. The data is in 5-channel teletype code, and, within the 7090 word, the character is right-justified. The data blocks associated with the TTY lines are six words long.

The high-speed output lines transmit data at the rate of 1,000 bits per second with eight bits per 7090 word, right-justified. The low order bits enter the channel first. The blocks associated with the high-speed output lines are 32 words long, but the trap indicating end of transmission occurs either when the 32nd word has been transmitted or when a word is transmitted that contains a 1 in the sign position.

3.4.2 Output Data to Cape Displays

The information to be displayed at the Cape is transmitted via the data communications channel over the high-speed lines as follows: an odd data frame followed by an even data frame (two data frames) is transmitted once a second during launch and abort, five times a minute during orbit, and 10 times a minute during re-entry. The timing is controlled by a clock interrupt or trap which tells the monitor system that a new frame of data is to be transmitted. The information to be transmitted is described in tables 2-1 to 2-13, and figures 2-2 to 2-13.

3.4.3 Teletype Output Data to Remote Sites

The Goddard computer generates acquisition messages and transmits these messages via the DCC to the remote sites. (See table 3-1.) Each message contains information concerning four points along the capsule's path over the site to which the message is addressed. For each of these points, the acquisition message contains the time, range, azimuth, and elevation at which the capsule should be acquired. This message is transmitted in the following format.

```
Y*Y*          (Y*Y* represents address code, see table 3-1.)
XXXXXXZ       (Greenwich mean time of transmission)
CCC           (CCC represents station abbreviation, see table 3-1.)
AQ            (Message type, AQ for acquisition)

HR MN SC RNGE AZM.H ELE.V
HR MN SC RNGE AZM.H ELE.V
HR MN SC RNGE AZM.H ELE.V
HR MN SC RNGE AZM.H ELE.V
XXXXXXZ       (Greenwich mean time of transmission)
              (Station abbreviation, see table 3-1.)
```

Radar range, azimuth, and elevation data is transmitted by teletype from radar tracking stations in a 34-character message as follows:

		Character	
Start of transmissions, sent once per transmission		J	
		J	
		Letters	
		Carriage return	
		Line feed	
		Letters	
Individual data frame	1	Carriage return	
	2	Line feed	
	3	Figures	
	4	Kind of data	2 = Real radar, 3 = Simulated, 7 = Last message
	5	Station	See Note A
	6	Identity	
	7	Radar type	0 = FPS-16, 2 = Verlort, 3-9 = Other
	8	Data validity	0 = Invalid, 2 = Valid
	9	Time Hours-Tens	
	10	Time Hours-Units	
	11	Time Mins-Tens	
	12	Time Mins-Units	
	13	Time Secs-Tens	
	14	Time Secs-Units	
	15–20	Azimuth	
	21–26	Elevation	
	27–33	Range	
	34	Oblique stroke	
End of each transmission		Blank	
		Figures	
		H	
		Letters	

Note A

Station Identification Codes

Station	Char. 5	Char. 6
Cape Canaveral	3	1
Grand Bahama Island	4	1
Grand Turk Island	5	1
San Salvador	6	1
Bermuda	0	2
Atlantic Ship	0	3
Grand Canary Island	0	4
Kano, Nigeria	0	5
Zanzibar	0	6
Indian Ocean Ship	0	7
Muchea	0	8
Woomera	0	9
Canton Island	1	1
Kauai, Hawaii	1	2
Point Arguello	1	3
Guaymas, Mexico	1	4
White Sands	1	5
Corpus Christi	1	6
Eglin	1	7
Goddard	1	8
Mercury Control Cen	1	9

Most significant character of azimuth, elevation, and range is transmitted first.

FIGURE 3-1. RAW RADAR DATA FROM REMOTE RADAR SITES TO GODDARD (TTY), MESSAGE FORMAT

TABLE 3-1. STATION TELETYPE ADDRESS CODES AND ABBREVIATIONS

Station	Address Code	Station Abbreviation
Cape Canaveral	YC	CNV
Bermuda (acquisition)	YB	BDA
Bermuda (nonacquisition)	YJ	BDA
Atlantic Ship	YA	ATS
Grand Canary Island	YN	CYI
Kano, Nigeria	YK	KNO
Zanzibar	YZ	ZZB
Indian Ocean Ship	YI	IOS
Muchea	YU	MUC
Woomera	YW	WOM
Canton Island	YL	CTN
Hawaii	YD	HAW
Point Arguello	YQ	CAL
Guaymas	YF	GYM
White Sands	YE	WHS
Corpus Christi	YX	TEX
Eglin	YR	EGL
Goddard (radar data to computer)	JJ	GSC
Goddard (not intended for computer)	GG	GSC
Mercury Control Center (nonpriority)	CC	MCC
Mercury Control Center (capsule priority)	PP	MCC
Mercury Control Center (T/M summary)	PP† SS†	MCC
MCC and Goddard (not for computer)	BB	
General broadcast to all sites	YY	

APPENDIX A

TERMS AND SYMBOLS

Appendix A defines the terms and symbols used in this manual.

a	The semimajor axis of the orbital ellipse.
a (as a subscript)	Apogee; the farthest point of the orbit from the Earth.
a_T	Acceleration, from telemetry.
A	Abort phase: from rejection of trajectory to escape rocket fire or retro-rocket fire.
A	Azimuth; in a range, azimuth, elevation system.
b	The semiminor axis of the orbital ellipse.
BECO	Booster engine cutoff.
CET	Capsule elapsed time.
d	Distance, in a horizontal direction, from the launch pad.
D/A	Digital-to-analog (converter).
E	Elevation angle; in a range, azimuth, elevation system.
ECTRC	Elapsed capsule time for retrofire, computer recommendation.
ECTRS	Elapsed capsule time of retrofire, setting in capsule clock.
EGT	Elapsed ground time.
GMT	Greenwich mean time.
GMTLC	Greenwich mean time of landing, computed.
GMTRC	Greenwich mean time for retrofire, computed, computer recommendation.

GMTRS	Greenwich mean time of retrofire based on present capsule setting.
Go—No—Go	The recommendation, by a computer, as to whether the flight should be continued.
GTRS	Ground time remaining until retrofire setting is reached.
h	Altitude above oblate (flattened at the poles) earth.
i	The inclination angle, which is the angle between the equatorial plane and the orbital plane.
ICTRC	Incremental capsule time for retrofire, or amount setting would need to be changed, computer recommendation.
ins, as a subscript	Point of insertion into orbit.
IP, as a subscript	Impact point, or point of landing.
L	Launch phase: from 2-inch liftoff to acceptance or rejection of the trajectory.
nom, as a subscript	The nominal value at any time.
O	Orbit phase: from acceptance of trajectory to retro-rocket fire.
r	Geocentric radius. The distance of the capsule from the center of the Earth.
$r - \bar{R}$	Height above spherical earth.
R	Range; in a range, azimuth, elevation system.
R	Re-entry phase: from escape rocket fire or retro-rocket fire to recovery.
$\bar{R}$	Reference radius of earth, which is 20,910,000 feet.
SECO	Sustainer engine cutoff.
Staging	Launch Vehicle booster dropoff.
t, t_e, or T_e	Time elapsed since liftoff.
T_n	Time remaining until sustainer engine cutoff.

ΔT	The nominal time, at any instant, before the retro-rockets can be fired to achieve impact in the next designated recovery area.
V	Velocity
V_R	Velocity required to achieve the planned orbit.
V_y	Velocity in a direction perpendicular (left or right) to the planned direction.
x, y, z	Rectilinear co-ordinates with origin at the launch pad as follows:
z	Vertical height, in nautical miles, in a direction normal to the Clarke 1866 Spheroid.
x	Distance, in nautical miles, in the direction of the planned launch azimuth and perpendicular to z.
y	Distance, in nautical miles, in a direction perpendicular to x and z. Positive values are north (to the left) of the planned launch azimuth.
$\dot{x}, \dot{y}, \dot{z}$	Velocity in the directions described for x, y, and z.
$Y-Y_{nom}$	The deviation of the actual value Y from a nominal value of Y for this particular trajectory.
X_p, Y_p, Z_p	IP 709 co-ordinate system. It is a right-hand system, giving vector position in geocentric inertial space, redefined at each computing cycle. The Z axis is the earth's rotational axis (positive north), and the X, Y plane is the equatorial plane. The X axis (positive value) passes through the Greenwich Meridian.
X, Y, Z	Mercury inertial co-ordinate system. In this system, the Z axis is the axis of rotation of the earth, with positive values northward; the X axis (positive value) is directed from the center of the earth toward the vernal equinox; and the Y axis lies in the earth's equatorial plane and forms a right-handed set. The origin is at the center of the earth.
γ (Gamma)	Flight path angle. Angle between a plane, tangent to an expanded earth sphere passing through the capsule, and the direction of flight.

γ_n (Gamma)$_n$
- 1 = Good data
- 0 = Computer is not computing guidance commands; not enough information

δ (Delta) B-GE computer flags, as follows:

δ_1
- 1 = Good data
- 0 = Computer is integrating rates of change to obtain R, A, E

δ_2
- 1 = Good data
- 0 = Computer is differentiating R, A, E to obtain rates of change.

δ_3
- 1 = Good data
- 0 = Computer is differentiating only for lateral rates.

E (Epsilon) The eccentricity of the orbit.

$$E = \frac{\sqrt{a^2 - b^2}}{a}$$

ξ (Xi), η (Eta), ζ (Zeta) Co-ordinate system used by Burroughs—General Electric Computer

It is a right-hand system.

The ζ axis lies along the earth's polar axis (positive northward), the ξ and η axes lie in the equatorial plane, and the ξ ζ plane contains the inertial point occupied by the phase center of the central rate antenna of the GE Mod III radar, at the time when the rate data used in any computing cycle was valid. The ξ η ζ co-ordinate frame does not rotate with the earth, although it is redefined each computing cycle.

λ (Lambda) Longitude, plus is East and minus is West.

$\lambda_{30\ sec}$ The longitude at which the capsule will land if retro-fire occurs 30 seconds from now.

λ_{PP} The present longitude of the capsule (present position).

$\lambda_{max\text{-}delay}$ The longitude at which the capsule will land if retro-fire occurs with maximum delay.

λ_P	The earth fixed longitude of the perigee (closest point to earth of the orbit)
ϕ (Phi)	Latitude, plus is North and minus is South
$\phi_{30\ sec}$	The latitude at which the capsule will land if retrofire occurs 30 seconds from now.
ϕ_{PP}	The present latitude of the capsule (present position)
$\phi_{max\text{-}delay}$	The latitude at which the capsule will land if retrofire occurs with maximum delay.